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This model state water monitoring program was developed by a panel of Federal and State professionals actively engaged in managing and operating monitoring programs. It is presented to others in monitoring and the field of water pollution control in order to: (1) Provide some basis to the States for building and operating water monitoring programs; (2) illustrate the various types of monitoring activities, their costs and their uses; and, (3) suggest to EPA Regions and States how they can best use monitoring resources in carrying out their responsibilities in pollution control and abatement.

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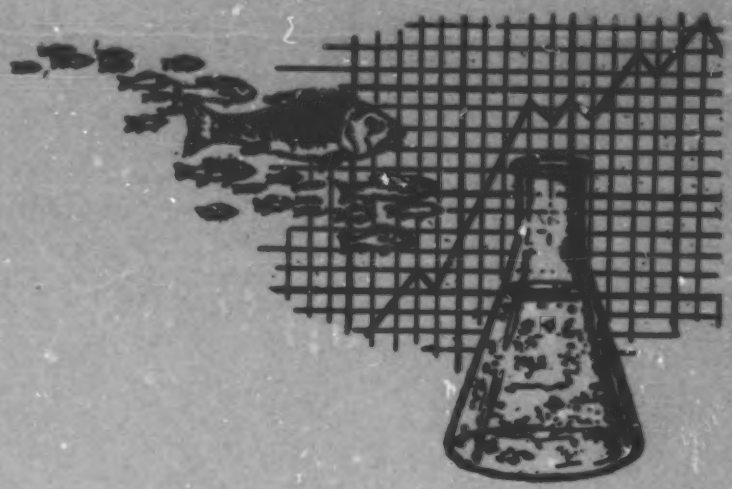

model state water monitoring program

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MODEL STATE WATER MONITORING PROGRAM

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June, 1975

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PART I
INTRODUCTION

This model state water monitoring program was developed by a panel of Federal and State professionals actively engaged in managing and operating monitoring programs. It is presented to others in monitoring and the field of water pollution control in order to:

- Provide some basis to the States for building and operating water monitoring programs;
- illustrate the various types of monitoring activities, their costs and their uses; and,
- suggest to EPA Regions and States how they can best use monitoring resources in carrying out their responsibilities in pollution control and abatement.

Such a program should fulfill most of the needs of the States in their water pollution control program and the monitoring requirements of the Federal Water Pollution Control Act Amendments of 1972 (PL 92–500). Since each State has its own unique water quality problems and organizational structure, each State should determine, along with the respective EPA Regional Office, relative levels of effort for the various monitoring activities.

The panel has set down the essential elements of a monitoring activity, explained its purposes and uses, suggested various procedures for conducting the activity, and estimated general manpower requirements for each. As operating experience is gained, certain of the procedures may change and requirements may be refined.

Additional comments, suggestions, and observations concerning the contents and use of this document are invited by the editors.

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PART II
PLANNING AND MANAGEMENT

INTRODUCTION

The purpose of this section is to place the monitoring element in its proper perspective as a fundamental part of the water pollution control program and to suggest ways of planning and managing the monitoring resources. The planning and management functions are concerned with management techniques for data collection, data evaluation, and data handling to provide the information needed to operate the State pollution control program successfully.

Figure II.1 illustrates the role of monitoring in relation to the planning, permitting, compliance, enforcement, and evaluation functions. It is obvious that if each function is to produce its required actions the proper type and amount of data must be provided by the monitoring program. With the large number of individual programs relying on the monitoring program for support, some system of priorities must be established for both the tasks to be accomplished, and the geographical areas of effort.

From the priority systems a schedule of work loads and outputs can be drawn up. Without such a schedule the monitoring program cannot be planned —it can only react. The day-to-day operation in the field will become a series of alternating crash projects and empty time.

Establishment of an efficient and adequate monitoring program will require that the persons responsible for monitoring maintain frequent and substantive contact with those programs needing information. Monitoring as a service function must anticipate the data needs and make provisions to fulfill these needs when called on. On the other hand, monitoring people are the closest to the pollution problem and may be in the best position to suggest future actions and priorities for planning, enforcement, or management based on their knowledge of the situations in the field.

BASIN AND/OR SEGMENT DEFINITIONS

States have found it useful for their planning and monitoring programs to subdivide large river basins and lengthy streams into segments (EPA Sec. 303(e) Regulations, 40 CFR Part 131.201(b)). The required segmentation makes work areas smaller and more manageable for such tasks as providing public information, briefing conferences, data review, revision of basin plans, and report preparations. Data from segments can be assembled for basin status report preparation or publication of water quality and discharge evaluations for the entire State.

Boundaries of the basin and stream sub-units should be selected recognizing the extent of pollution, number of discharges, extent and magnitude of significant stream impact, location of water resources projects, populations affected, etc. Generally, water quality situations within the sub-unit should be separable to some degree from those of contiguous subunits

SEGMENT PRIORITIES

The resources required to meet each and every monitoring need will rarely be available during any given fiscal year. Therefore, good program management will require that a priority system be established and followed. The priority system should reflect the management decisions that must be made within the next 18 to 24 months. The priority system should reflect an objective view of the location and severity of pollution problems. Some suggested factors for inclusion in the segment priority rating system follow.

Severity of Pollution. For basin subunits and stream reaches.

- Ratio of total waste discharged in subbasin to total estimated 7 day–10 year low flow leaving basin.
- Number of waste treatment facilities in subbasin.
- Total waste flow in subbasin.

Population Affected.

- For basin subunits, total population in subunit.
- For stream reaches, population affected by waste treatment measures.

Treatment Levels. For stream reaches and subbasins.

- Total untreated waste flow.
- Total primary treated waste flow.
- Total secondary treated waste flow.
- Total advanced treated waste flow.
- Number of overloaded facilities.
- Total design flow of overloaded facilities.
- Estimated total nonpoint source contribution.

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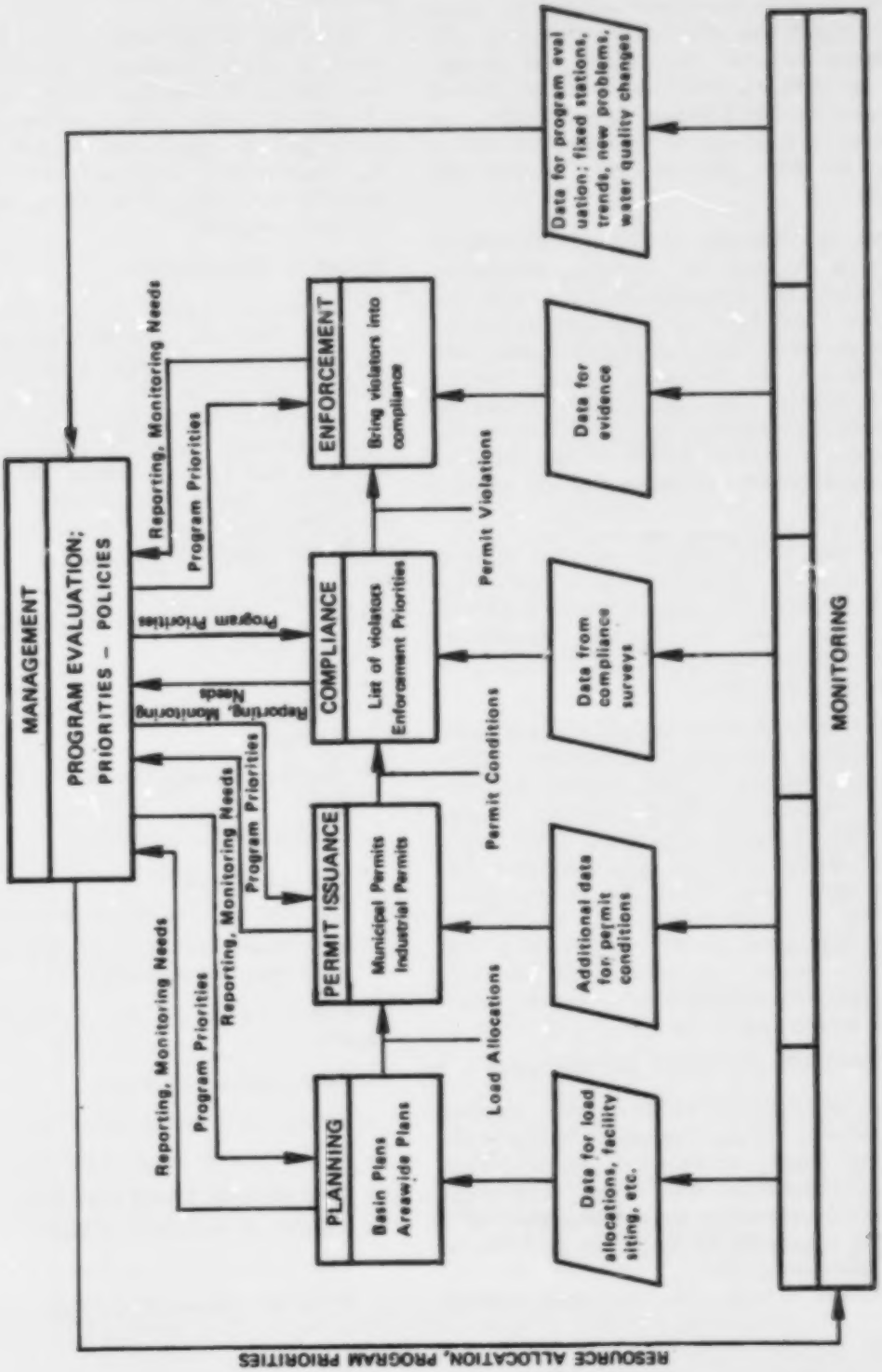
FIGURE II.1

MONITORING IN PERSPECTIVE



Eutrophication.

- For subbasins, ratio of land to lake and impoundment area.
- For stream reaches, downstream lakes or impoundments.

Waters Below Standards. For subbasins and stream reaches, estimated total miles of streams having water quality standards violations.

WORK PLAN, STATE STRATEGY, EPA COORDINATION

Once data and analysis needs have been identified and prioritized, the State can design its strategy and work plans for monitoring in the upcoming year. There are three basic types of monitoring and monitoring-related activities which the State may design into its work plan. These three can be subdivided according to the goal of the activity and include the items shown in Figure II.1.

In general, effluent monitoring is related to specific, permitted discharges, intensive surveys to specific geographical areas, and fixed station monitoring to large geographical areas of statewide interest. A particular activity may be of 1-day duration or continue for a number of years. It may be very simple or very detailed and complex. The point is that it should be designed to meet the specific need for information.

The various monitoring activities should be carefully coordinated. For example, operations and maintenance inspection activities and compliance monitoring within a specific area should be scheduled at the same time as an intensive survey in that area. Intensive survey design should include data gathering to be used for evaluation and, where necessary, modification of the trend monitoring station network.

A suggested method the State can use to distribute its workload is as follows.

1. Define each monitoring or monitoring related need as a work project. Assign a professional staff member to be responsible for the completion of the work. His duties will include determination of feasibility, detailed design of the project, field reconnaissance, field supervision, data compilation and evaluation, report composition, and recording of manpower and money resources used.
2. Define, in narrative form, the purpose, scope, and level of detail for each work project. Make each work project as small as possible to maximize flexibility.
3. Estimate the number and type of field, laboratory, and office assignments to be accomplished, e.g., sampling runs, procurement of sampling supplies, field trips, field stations, number and type of lab analyses, and extent of final report.
4. Estimate in man-days the number and type of personnel required.
5. Where work involves a consultant or cooperator contract, state the expected result and cost of the contract.
6. Once all the manpower and money resources available have been allocated to the work projects, prioritize and schedule the projects, combining as many as possible.

It is useful to allocate resources to reserve projects to allow for a certain number of unforeseen events; e.g., enforcement actions, complaint investigation. It is also advisable to have a number of work projects designed and waiting in reserve in case the original projects are accomplished earlier than anticipated or unforeseen events allowed for do not occur. These reserve projects should be those of a high priority for the following fiscal year.

FEATURES OF THE WORK PROJECT SYSTEM

- Permits the design of a monitoring and related workload commensurate with the staff and money available.
- Permits the scheduling of field and office work in coordination with the analytical laboratory.
- Promotes professionalism by providing for delegation of supervisory responsibility among the staff.
- Provides for orderly accomplishment of work from concept through final report.
- Provides for work accomplishment on a priority basis.
- Provides the basis for improving cost estimates.
- Allows continuing evaluation of personnel performance and training requirements.

AGENCY NEEDS

Once the workload has been distributed based on resources available, the agency or agencies responsible for monitoring and related activities can compare the available workload against the requested workload which would appropriately meet the State's needs. Annual manpower and money needs can then be documented.

The documentation of resource allocation and needs will improve with each fiscal year with accurate recordkeeping by responsible personnel. This is important information to have available when audits are made and when dealing with State legislatures, EPA, and the Congress.

Equipment needs, personnel needs, and space needs should be programed as far in advance as possible since purchasing and space allocation procedures are lengthy and involved. If shortages in these areas cannot be avoided, temporary relief may be found by using personnel of other State, Federal, or academic institutions or with consultants.

FIELD WORK

Field work can be designed and accomplished using the suggested technical guidance which follows in this document. Each field work item should be designed so as to produce the specific result needed. Thus, the type, amount, and level of detail of the work should be commensurate with the need to be filled. Careful consideration should be given to the skills to be employed, the number of stations to be established, the parameters to be analyzed, and the sampling timing and frequency.

DATA BASE AND INFORMATION HANDLING SYSTEM

The quality of the State's data base and data handling system contributes as much to the success and efficiency of the State program as any other item. Considerations in designing the State system include the following.

1. Information should be obtainable on a subwatershed and segment basis to facilitate planning.
2. Output formats should be designed to facilitate publication of documents such as statutorily required reports, discharge lists, segment priority lists, public information reports, etc.
3. Output formats should be designed to facilitate work project reports.
4. The State should use the storage and retrieval (STORET) computer system, or operate its own system which is compatible with this system.

Whatever the design for the State's system, its purpose is to make current data readily available to users in a timely fashion with a minimum of manual handling. The well-designed system will also enhance data analysis and aid the management decision process.

The data handling and processing needs of all components of water monitoring programs differ only in detail. The general needs are the same throughout whether the system is manual, microfilmed, or computerized, or any combination of these.

Timely Reporting. For monitoring data and information to be useful to the planning and enforcement functions of a water pollution abatement program, it must be readily available in an orderly form within a time frame consistent with planning and enforcement activity requirements. Preparation of data for input to the data system should be done concurrently with the field survey, sampling activity, or permit application receipt. Input should follow immediately after data review and correction.

Quality Control During All Phases of Data Handling From Logbook or Bench Card Entry, or Permit Application Receipt to System Output. Normally will include the following steps.

1. Review of original documents by other than the original analyst, or permit application reviewer.
2. Spot checking of data tabulations or transcriptions by other than the original transcriber.
3. Plotting data, as appropriate, to show anomalies.
4. For data to be entered on computer files, verification both by verifying machines and visual review of printouts of keypunched data.
5. Provide computer input system with screen and edit routines (e.g., ranges not to be exceeded). On output, provide at least minimal screening (e.g., printing outliers of a record)

to prevent acceptance of unexpected line errors, etc.

Established Methods for Basic Data Manipulation. The same statistical or other mathematical techniques should be used for at least initial interpretation of monitoring data within a single program to allow for comparison of data among studies, for the development of trend analyses, or for comparison of permits among similar industries.

Clearly Defined and Documented Methods for Using the System. Straightforward instructions should be provided to simplify training and system use. Similarly, straightforward instructions should be available for production of standard data reports.

Appropriateness to the Overall Monitoring System and to the Program Needs Which the Stored Data and Information Will Serve. As the size and complexity of the monitoring program should be scaled to the planning and enforcement functions, the size and staffing of the State's monitoring program will dictate the type of data handling and processing system needed. In some cases, a logbook and file cabinet will suffice; in others, a sophisticated computer system may be necessary.

Ordinary rules of good data handling should apply in any case:

1. Transcribe data the fewest number of times to minimize human error.
2. If possible, use logbooks and bench cards which allow direct keypunching or other tabulation for storage.
3. Use an open-ended system to allow for unforeseen developments (e.g., atypical values, permit changes or amendments), or advancing technology (e.g., lowered limits of detectability).
4. Use standard data element names (e.g., parameters, station numbering schemes, units of measurement) to allow comparability of data.
5. Assume that no reasonable and achievable amount of quality control is too much.
6. Protect master files by keeping a duplicate of every transcription in a safe place.

While the outputs needed from a data handling and processing system vary with the program they serve, the form most generally useful is the exception report. For compliance monitoring, for example, some systematic method of exception reporting (e.g., detecting and flagging violations) probably will be necessary. Some of the types of exceptions in compliance monitoring data files would be:

- Incomplete application.
- Obviously incorrect application.
- Missed implementation deadlines.
- Effluent violation.
- Technically inadequate permit.
- Nonrenewal or failure to update permit information.

In other types of monitoring data, exceptions may include:

- Water quality below standards.
- Development of apparent trends.
- Rapid changes in water quality due to improvements or degradation of waste treatment facilities.
- Anomalies in otherwise consistent records, such as the sum of chlorides, sulfates, etc., being significantly different from TDS.

Whether manual or completely computerized, capability for such reporting should be a part of the data handling and processing system.

REPORTS

Reporting the results of a water quality monitoring survey or other activity is as important as the study itself in terms of putting to use the knowledge gained. The first of the two basic types of reports normally needed is the data report. The data processing and handling system should be designed to provide such reports with a minimum of manual handling. Whether the subject is a periodic report on a fixed station or trend network, an intensive survey, or a compliance inspection study, the basic data report should include the following.

- A brief description of:
  a. purpose of the report
  b. purpose of the study
  c. area of study.

- Summary of conditions as indicated by the data.
- Presentation of basic data.

The second type of basic report is the interpretive report which centers on conclusions drawn from, and recommendations based on, data concerning the following.

- Problem identification.
- Alternative solutions:
  a. documentation of solutions
  b. predicted effects of solutions.
- Changes from previously reported status.
- Priority of proposed actions.
- Discharge characteristics and conditions.
- Water quality conditions.
- Biological conditions.
- Socioeconomic conditions:
  a. description of area
  b. demographic status and trends
  c. water uses
  d. land uses.
- Description of study and methods.
- Data presentation.

These interpretive reports, particularly proposed solutions and their priorities, form the major input of the monitoring program to the management function of the water pollution abatement program whether the original study was a trend examination, an intensive survey, a compliance study, a special project, or an evaluation of the effectiveness of the State program itself. The interpretive report is the primary instrument for communicating the findings. It should be direct and to the point.

OUTSIDE DATA

There are a number of data types that the State agency or agencies involved in water quality management planning may not have responsibility for such as land use, population projections, socioeconomic factors, etc. The agency will generally obtain this information from outside sources for use in its analysis effort.

ANALYSIS

Analysis includes data evaluation, mathematical water quality simulations, aquatic community interpretation, statistical analysis, etc. It is important to note that analysis includes a review of the impact and ramifications of management decisions in regard to the overall water quality management program.

TRAINING

Implicit in the operation of a water monitoring program is the continual need for manpower training. These needs occur in all facets of the operation, but training needed is most often of three basic types: introductory/orientation training, skills upgrading, and refresher courses. The first is typified by the situation in which a general engineer is hired and requires some basic short course orientation in applying his broad skills to a specific area such as water data interpretation. The second is frequently needed because of improvements in technology resulting in the introduction into a working situation of more sophisticated or complex analytical or computing devices. Refresher courses would typically consist of, or include seminars or workshops in chain-of-custody, analytical quality control, or sampling procedures.

The training needs of any operation vary, of course, with the requirements of the individual program itself. Some basic training requirements are common to some part of the staff in almost all water monitoring programs, however. These include exposure to:

- Survey and network design criteria.
- Sampling procedures and handling of sampling devices.
- Chart and map reading.
- Sample preservation and proper packaging.
- Field determination techniques and devices.
- Chain-of-custody procedures.
- Analytical quality control.
- Statistical quality control.
- Operation and use of new laboratory devices.
- Data handling and processing techniques and devices.
- Data interpretation and evaluation.

While this list is not all-inclusive, it represents the most often needed training in a water monitoring program. Some consideration to providing at least these types of training should be given in planning any year's activities. An average of approximately one-man week per staff member should be allocated annually. Costs will vary according to type and duration of training.

SUMMARY

The state monitoring process is built on the following principles.

- The ultimate goal of monitoring is to fulfill the data and information needs of the State pollution control program.
- Monitoring is part of the overall state program, not an end in itself.
- Only justifiable work is to be done.
- Monitoring is used to collect, evaluate, and present data and other information in a rational and methodical manner.
- The annual monitoring workload is commensurate with the money and manpower resources available.

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PART III
AMBIENT WATER QUALITY MONITORING

INTRODUCTION

This part of the model program deals with the following basic components of the monitoring program.

- Fixed station monitoring networks.
- Intensive surveys.
- Ground water monitoring.

Each of these aspects of the monitoring program is discussed separately in five broad categories.

General. A general discussion of the various aspects of the monitoring activity.

Purposes. The general reasons for, and the purposes of, the activity being discussed.

Design. This section discusses station locations.

Operation. Some of the aspects of conducting the monitoring; primary emphasis is on sampling frequency and parametric coverage with some discussion of data handling and reporting.

Resources. An estimate of the manpower requirements for the monitoring activity with some reference to equipment requirements.

Although three basic monitoring activities are discussed separately in this section, they should not be considered as separate activities in actual practice. Comprehensive data interpretation will require that all monitoring data be considered together.

FIXED STATION MONITORING NETWORKS

General

The fixed monitoring network is a system of fixed stations that are sampled in such a way that well-defined histories of the physical, chemical, and biological conditions of the water and sediments can be established. In general, other monitoring data will be needed to explain, in detail, the trends observed at the fixed stations. Thus, a high level of coordination between the fixed station monitoring network and other monitoring activities is essential for developing a useful data base.

For the purposes of this discussion two types of fixed monitoring networks are defined; a primary network and a secondary network. The main difference between the two is that the primary network is designed to meet a wide range of objectives while secondary network stations are located and sampled for the purposes of meeting more specific and short term objectives. Primary network stations are sampled throughout the year and are designed to be operated for an extended time.

The discussion that follows is primarily directed towards the primary monitoring network. However, the same principles and design criteria may be applied, as appropriate, to secondary monitoring stations.

Purposes

The basic objective of the fixed monitoring network is to provide data and information that, when taken in combination with other data, will:

1. Characterize and define trends in the physical, chemical, and biological condition of the State's surface waters, including significant publicly owned lakes and impounded waters.
2. Establish baselines of water quality.
3. Provide for a continuing assessment of water pollution control programs.
4. Identify and quantify new or existing water quality problems or problem areas.
5. Aid in the identification of stream segments as either effluent limited or water quality limited.
6. Act as a triggering mechanism for intensive surveys, enforcement proceedings or other actions.

To meet these objectives it is essential that the fixed station monitoring networks be established and maintained in a uniform and logical manner. This section presents some of the criteria upon which a monitoring network can be designed and operated. Since many monitoring and water quality problems are unique to a given area or State, this section should be viewed as a baseline from which the actual monitoring networks may differ.

Network Design

The general characteristics of the water body are most important in locating fixed network stations. This information can be obtained through intensive surveys or from historical data. If no such data are currently available, then a visual or superficial quantitative/qualitative survey (reconnaissance survey) would be useful in siting stations. The use of predictive tools, such as mathematical models, can be

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particularly useful in selecting station sites, especially in those cases where such tools were utilized to develop the current pollution control plan for an area.

Two terms, "critical" and "representative" which can be used to describe general station siting criteria may be defined as follows.

Critical Site. That location in the surface water that displays or has the potential for displaying the most pronounced water quality or biological problems. The data from a critical site will show changes in water quality conditions at that site and may act as a trigger for intensive surveys. An example of a critical location is the area of minimum dissolved oxygen within the water body.

Representative Site. A location in the surface waters that will produce data that reflects the general condition of the majority of the water body in which it is located. The selection of such points will require a historical knowledge of the characteristics of the water body. The official definition in 40 CFR Part 35, Volume 39, Number 168 reads: "The term 'representative point' means a location in surface waters, groundwaters, sewer systems, or discharger facilities at which specific conditions or parameters may be measured in such a manner as to characterize or approximate the same at some other location, or throughout a reach, segment, or body of water."

There are three basic types of sampling that may be performed at fixed monitoring stations. These are: (1) physical and chemical sampling of the water column, (2) biological sampling of the water column and benthos, and (3) physical and chemical sampling of the sediments. Due to the varying nature of stream characteristics and water quality, it often is not necessary to perform all of these sampling activities at every location. The following general criteria apply:

Biological Sampling. At locations specified in the trend monitoring requirements for biological monitoring (see Part IV, BIOLOGICAL MONITORING).

Sediments. In sink areas as determined by intensive surveys, reconnaissance surveys, and historical data. A major concern of sediment monitoring will be to assess the accumulation of toxic substances.

Water Column. The following station locations are suggested for the chemical and physical sampling of the water column. Biological and sediment stations should also be established at these locations, as appropriate.

- At Critical Locations in Water Quality Limited Areas

  Stations should be located within areas that are known or suspected to be in violation of water quality standards, ideally at the site of the most pronounced water quality degradation. The data from these stations should gauge the effectiveness of the pollution control measures being required in these areas.

- At the Major Outlets From and at the Major or Significant Inputs to Lakes, Impoundments, Estuaries, or Coastal Areas That Are Known to Exhibit Eutrophic Characteristics

  These stations should be located in such a way as to measure the inputs and outputs of nutrients and other pertinent substances into and from these water bodies. The information from these stations will be useful in determining cause/effect relationships and in indicating appropriate corrective measures.

- At Critical Locations Within Eutrophic or Potentially Eutrophic Lakes, Impoundments, Estuaries, or Coastal Areas

  These stations should be located in those areas displaying the most pronounced eutrophication or considered to have the highest potential for eutrophication. The information from these stations, when taken in combination with the pollution source data, can be used to establish cause/effect relationships and to identify problem areas.

- At Locations Upstream and Downstream of Major Population and/or Industrial Centers Which Have Significant Waste Discharges into Flowing Surface Waters

  These stations should be located in such a way that the impact on water quality and the amounts of pollutants contributed can be measured. The information collected from these stations should gauge the relative effectiveness of pollution control activities.

- Upstream and Downstream of Representative Land Use Areas and Morphologic Zones Within the State

These stations should be located and sampled in such a manner as to compare the relative effects of different land use areas (e.g., cropland, mining area) and morphologic zones (e.g., piedmont, mountain) on water quality. A particular concern for these stations is the evaluation of nonpoint sources of pollution and the establishment of baselines of water quality in sparsely populated areas.

- At the Mouths of Major or Significant Tributaries to Mainstem Streams, Estuaries, or Coastal Areas

  The data from these stations, taken in concert with permit monitoring data and intensive survey data, will determine the major sources of pollutants to the State's mainstem water bodies and coastal areas. By comparison with other tributary data, the relative magnitude of pollution sources can be evaluated and problem areas can be identified.

- At Representative Sites in Mainstem Rivers, Estuaries, Coastal Areas, Lakes, and Impoundments

  These stations will provide data for the general characterization of the State's surface waters and will provide baselines of water quality against which progress can be measured. The purpose of these stations is not to measure the most pronounced areas of pollution, but rather to determine the overall quality of the State's water. Biological monitoring will be a basic tool for assessing the overall water quality of an area.

- In Major Water Use Areas, Such as Public Water Supply Intakes, Commercial Fishing Areas, and Recreational Areas

  These stations serve a dual purpose; the first is public health protection, and the second is for the overall characterization of water quality in the area. Determining the presence and accumulation of toxic substances and pathogenic bacteria and their sources are primary objectives of these stations.

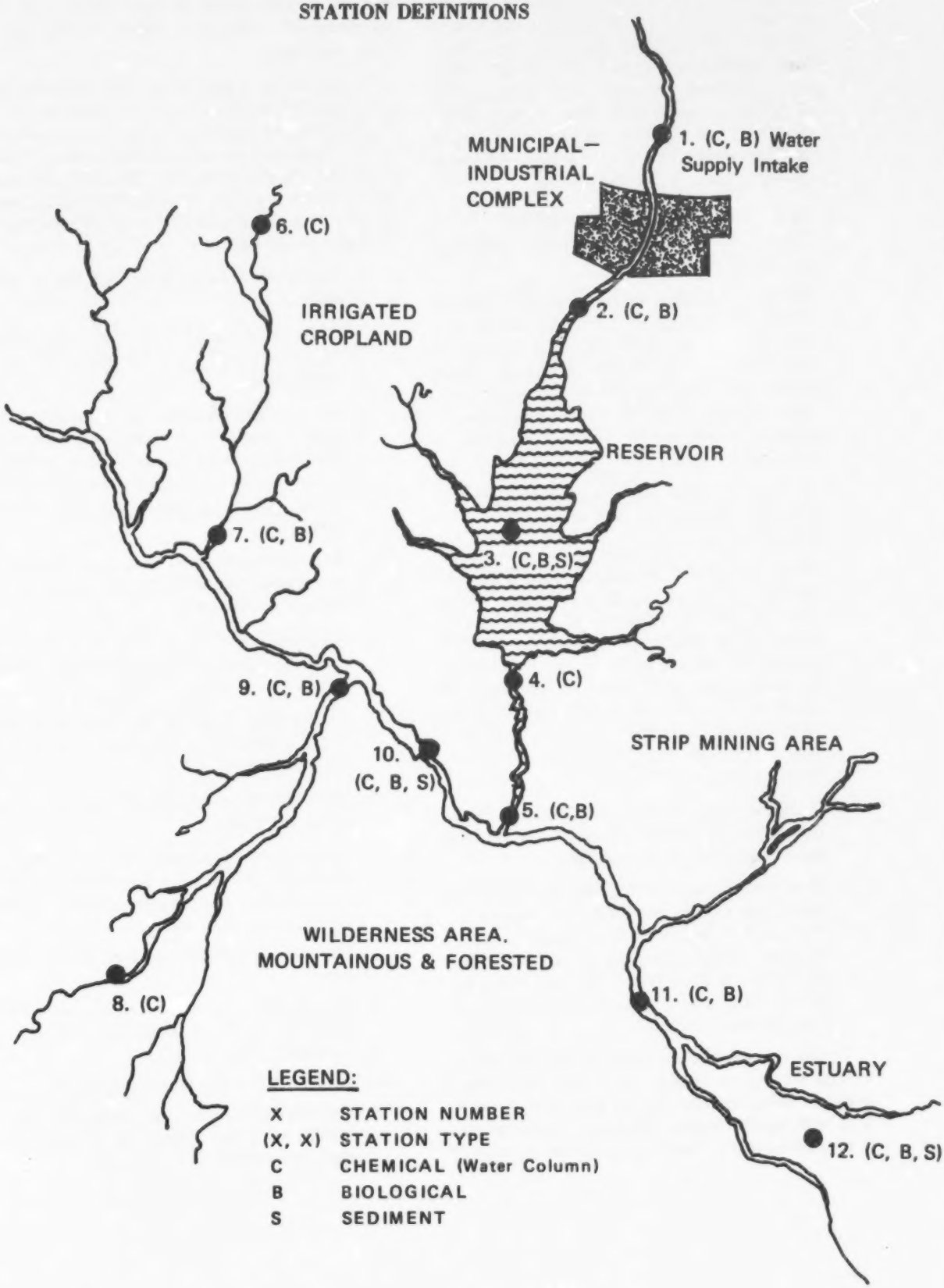
To the extent possible these stations should be located in such a manner as to aid cause/effect analyses. Some station requirements may be such that, with careful station siting, one particular station could meet the criteria of a number of types of stations. Caution should be exercised to avoid compromising the worth of a station for the sake of false economy.

In general, the quality of a monitoring network is not judged solely by the number of stations. A few critically located stations may be extremely valuable while a large number of randomly selected stations may yield meaningless data. Resource constraints will probably limit the total number of stations in the fixed network. Figure III.1 shows some examples of station definitions.

The stations shown on Figure III.1 are described as follows:

1. At a water supply intake; upstream station of a pair bracketing a municipal and industrial center.
2. At a critical location in a water quality limited segment; downstream station of a pair bracketing a municipal and industrial center; mouth of a significant input to a reservoir known to exhibit eutrophic characteristics.
3. At a critical location in a reservoir known to exhibit eutrophic characteristics; in an area of recreation.
4. Upstream of a major land use area (strip mining); major outlet from a eutrophic reservoir.
5. Downstream of a land use area (strip mining); mouth of a significant tributary to mainstem river.
6. Upstream of a major land use area (irrigated cropland).
7. Downstream of a land use area (irrigated cropland); mouth of a significant tributary; representative site for other streams passing through same land use.
8. Upstream of a major land type area (wilderness).
9. Downstream of a major land type area (wilderness); mouth of significant tributary to mainstem river.
10. Representative site in mainstem river.
11. Representative site in mainstem river, mouth of major input to a potentially eutrophic estuary.

FIGURE III.1
STATION DEFINITIONS



12. Representative site in estuary, recreational area, shellfish harvesting area.

Network Operation

The primary network should be operated uniformly. The secondary network, because of the possibility of varying objectives for each station, may not be uniform in its operation. Following is a general discussion of the sampling frequencies and parametric coverage for fixed network stations.

The frequency at which a fixed network station is monitored will be a function of the variability of the chemical, physical, and biological conditions inherent in the water body. In general, the data collected at primary stations must be representative of the variations in water quality and changes in pollution occurring over the course of a year, whereas the data collected at secondary stations must satisfy some specific objectives. This may require varying sampling frequencies, depending upon the season, nature of pollution sources, time of water travel from station to station, tidal and diurnal variations, etc.

The following general principles should apply to the operation of primary network stations and to secondary stations, when appropriate.

1. Parametric coverage at primary stations should not be limited to those substances that are known to be a problem, but should also include substances that can reasonably be expected to become a problem. One of the objectives of this network is to identify new problems as well as to monitor existing ones.
2. Periodic sampling should be performed specifically for toxic substances in both the water column and the sediments. If these substances are present in sufficient quantity to present a problem or are displaying trends that represent an actual or potential problem, then they should be incorporated into the regular set of parameters monitored at that station.
3. Parameter coverage should be as uniform as possible throughout the entire primary monitoring network. This will permit detailed and quantitative comparisons from one station to another. Table III.1 presents a suggested minimum for parametric coverage and sampling frequency at primary network stations.
4. All monitoring performed in the fixed networks should be in accordance with the quality assurance requirements set forth in this document (see Part VI, QUALITY ASSURANCE). The collection of accurate data using uniform data collection and analysis techniques is essential in maintaining good quality control within the fixed monitoring networks.
5. Of primary importance is the maintenance of the compatability of the data collected within the fixed networks with other monitoring activities. The data generated by the fixed networks should be periodically reviewed for the purposes of evaluating individual station locations, parametric coverage, and sampling frequency with respect to the objectives of the networks.

Resources

The resource estimates given here are based on primary network stations. Estimates for secondary stations are not given because of their flexibility.

A single station is assumed to be the basic building block. Consequently, this activity needs a field capability to collect samples, perform analyses such as pH, dissolved oxygen, and temperature on site. If the sample station is over 6 hours travel time from the laboratory, then some time-dependent determinations, such as fecal coliforms, should be completed at the station site.

Estimates for laboratory support for a station are on the basis of 30 analyses per station plus 3–6 (10–20%) additional analyses (standard additions and duplicate analyses) for quality control.

Table III.2 shows the resource estimates on a per-station basis.

INTENSIVE SURVEYS

General

Intensive surveys are a major element in the monitoring program. Fundamentally, the intensive survey: (1) bridges the gap between the data bases generated by effluent monitoring and fixed station monitoring; (2) provides the definitive basis for understanding and describing receiving water quality and the mechanisms and processes that affect water quality; (3) provides the documentation required to explain the trends observed at fixed network stations;

TABLE III.1

RECOMMENDED MINIMUM PARAMETRIC COVERAGE AND SAMPLING FREQUENCIES FOR THE PRIMARY MONITORING NETWORK

Parameters	Frequency	Remarks
(1) Streamflow	Concurrently with water quality measurements	Determined at all stations in rivers and streams
(2) Stage or water surface elevation	Concurrently with water quality measurements	Determined at stations in lakes and reservoirs where water quality variations are related to stage variations
(3) Tidal stage	Concurrently with water quality measurements	Determined at all stations in tidal water bodies. Sampling at a given station must be conducted at a specified tidal stage, preferably at slack tide, to permit meaningful analysis
(4) Parameters specifically cited in the State's water quality standards	Monthly	As specified for the given sampling area
(5) Parameters known or suspected to be associated with major upstream pollution sources	Monthly	
(6) Heavy metals and other toxic materials, oil and grease, COD, total Kjeldahl N, pesticides	Annually	In sediments at sediment stations
(7) Dissolved oxygen, temperature, pH, specific conductance, total phosphorus, total Kjeldahl N, NO_2+NO_3, TOC, COD	Monthly	At all stations
(8) Biological parameters (as specified in Part IV, BIOLOGICAL MONITORING)	As specified in Part IV, BIOLOGICAL MONITORING	At appropriate stations
(9) Biologically related chemical and physical parameters and observations including chemical analysis of tissue	Annually	At selected stations as necessary to determine the presence, extent, and impact of toxic pollutants
(10) Total Coliform bacteria, fecal Coliform bacteria	Monthly Monthly	At all stations, including commercially harvestable shellfish areas, as specified by the National Shellfish Sanitation Program
(11) Fecal streptococci	Monthly	At all rural freshwater stations
(12) Specific pathogens e.g. (salmonella)	Monthly	As appropriate

TABLE III.2

RESOURCES ESTIMATES PER STATION PRIMARY NETWORK

Activity sampling	Time required	Equipment required	Remarks
a. By cooperator	One man trained through standard 2-week course approximately 4 hours per station per sample	BOD incubator, pH meter, DO meter, thermometer, coliform apparatus, sample collecting device, containers, preservative, shipping containers	Paid cooperators in remote areas shipping preserved samples into laboratory are economical
b. By agency personnel	Six stations per day using two men	Use of mobile or temporary laboratories necessary for trips over 6 hours distance from laboratory. BOD work on site is necessary unless time approaches 8 hours	
Laboratory analyses	One man-week per three samples	Complete operating water quality laboratory	Includes data summary, glass washing and some secretarial help. Assume chemistry and microbiology competency in the laboratory
Data handling	One man-day per four stations	Computer support	Includes keypunching, verifying, inclusion in laboratory analysis management system, entry into STORET and manipulation after sufficient base has been collected

and, (4) is a method for determining the ultimate fate of pollutants in the water environment.

However, some generalizations concerning the overall nature of intensive surveys and their planning and execution follow.

1. Repetitive measurements of water quality are made at each station (sources and receiving water). The stations will comprise a short, very dense, sampling network throughout the duration of the field effort.
2. The duration of an intensive survey is dictated by the objectives of the survey, with 3 to 14 days being typical for freshwater streams, lakes and reservoirs. Surveys in tidal bodies are typically more complex and longer in duration.
3. The measurements taken during an intensive study vary. A study may be oriented towards one particular type of data (chemical, biological, sediment, etc.) or it may involve the collection of many types of data.
4. Point sources within the survey area are monitored during the study.

Purposes

Intensive surveys are conducted within the framework of a well defined set of objectives. Intensive

surveys are support activities, that are conducted in response to the needs and objectives of operational programs, principally water quality planning and enforcement. Some of the major uses of intensive surveys follow.

1. To set priorities for establishing or improving pollution controls.
2. To support and to set priorities for enforcement actions.
3. To determine quantitative cause and effect relationships of water quality for making load allocations, assessing the effectiveness of pollution control problems, or for developing alternative solutions to pollution problems.
4. To identify and quantify nonpoint sources of pollution and to assess their impact on water quality.
5. To assess the biological, chemical, physical, and trophic status of publicly owned lakes and reservoirs.
6. To provide data for the classification or reclassification of stream segments as being either effluent limited or water quality limited.
7. To evaluate the locations and distribution of fixed monitoring stations.
8. To determine if toxic substances are entering the State's waters and, if so, to identify and establish priorities for controlling the sources.

The above list of objectives for intensive surveys should not be viewed as being restrictive. Certainly, there will be other valid reasons for conducting intensive surveys. The above objectives, however, should also be considered mutually compatible. The incremental cost of expanding a single purpose survey into a multipurpose survey should always be evaluated prior to conducting the survey.

Listed below are some specific examples of intensive surveys, the purposes they serve, and the general characteristics of each of these types of surveys.

Compliance Monitoring—Segment Surveys. These are short term studies that generate data for the purposes of: (1) Detecting significant waste sources that are not permitted; (2) assessing compliance with permit conditions; (3) assessing the water quality response to either compliance or noncompliance with permit conditions; (4) developing priorities for enforcement actions; and (5) evaluating self-monitoring reports. In the simplest case this type of survey will have the following characteristics.

1. Duration of up to 5 days.
2. Composite samples of all permitted discharges in survey area.
3. Sufficient receiving water samples to define the stream profiles and distributions of the substances of interest. (In tidal bodies, receiving water samples should be taken during slack tide conditions.)
4. Parametric coverage limited to those substances that are known or suspected of being discharged and those substances that are impacted by discharged substances, such as dissolved oxygen. Biological and sediment samples may be desirable especially when toxic substances are known or suspected to be present.

Load Allocations—Development and Refinement. The survey requirements for load allocations are largely dependent on the method or technique used to make the allocations. All water quality prediction methods require values for in-stream constants, such as biochemical rate constants, which must be determined from survey data. Normally, more than one intensive survey will be required for a load allocation. Typically, a water quality prediction method must be calibrated and validated before it can be used with confidence. The data requirements for the calibration process may be more comprehensive than for validation. In general, studies for load allocations development will be more involved than compliance monitoring segment surveys. Most load allocation surveys will have the following characteristics.

1. Duration of up to 14 days.
2. Samples of waste sources within survey area; either composite or grab samples, depending on the analysis requirements (usually composite).
3. Sufficient receiving water samples to define the stream profiles and distributions of the substances of interest. (Samples should be

taken during slack water conditions in tidal bodies.)

4. Physical and hydrological data will be needed for the development and calibration of predictive tools.

5. Biological and sediment data as required.

6. Parametric coverage at least as extensive as in compliance segment surveys. Additional parameters may be required, depending on the complexity of the system and the requirements of the predictive tools used.

7. Specialized methodology may be required for such measurements as reaeration rate, in-situ sediment oxygen uptake, time of water travel, dispersion, etc.

8. Surveys will usually be conducted during critical water quality periods, such as low flow periods.

Investigations of Nonpoint Sources of Pollution. Surveys will be for the purposes of: (1) Identifying and quantifying nonpoint sources of pollution; (2) evaluating their impact on the receiving water quality and biota; and (3) providing the physical, chemical, biological, and hydrological data necessary for the development and evaluation of abatement measures. Studies of nonpoint sources will be similar in level of effort to load allocation surveys. However, their timing will be geared to the hydrological conditions (e.g., streamflow and rainfall) that are associated with nonpoint pollution sources rather than to critical water quality conditions, although the two conditions may coincide. The quantitative identification of all point sources is essentially in nonpoint source investigations. Typically, nonpoint source loadings are obtained by mass balances: Subtracting point source loads from the total load. Information about land and water use practices, topography, and geology should also be obtained for the purpose of identifying the sources of nonpoint loadings. Generally, several studies under different hydrological conditions will be required to fully assess the nonpoint sources of pollution in an area. Some features of nonpoint source surveys are:

1. Samples of waste sources are taken. These will normally be composite samples.

2. Sufficient receiving water samples to define stream profiles and distributions of the substances of interest. Samples representing cross-sectional averages will normally be required for computing loads. In tidal areas, enough samples should be taken to define the net mass flux over a tidal cycle.

3. Parametric coverage will vary widely from area to area, depending on the known sources of pollution. Those substances that are known or suspected of being discharged from either point or nonpoint sources should be monitored. Analysis of the point source samples should include those substances that are known or suspected of originating from nonpoint sources, even if they are not specified in the permit.

4. Biological and sediment samples as required to evaluate impact of nonpoint pollution sources and in the case of suspended sediments, to evaluate the magnitude of the problem.

5. Specialized measurements and sampling intervals.

6. Hydrological and physical data.

Basin Status Surveys. In the broadest sense, these surveys are conducted to assess the total condition of a basin or portion of a basin and to provide data for the evaluation of the pollution control program. As such, they are comprehensive and will require the collection of many forms of data. Basin status surveys will require a larger resource commitment than other intensive surveys with more specific objectives. These surveys will satisfy the objectives of a number of other types of intensive surveys because of their completeness. For this reason they should be considered as multipurpose surveys with their primary objective being to assess the overall condition of the water body. Some of the general characteristics of basin status surveys will be:

1. Duration of up to 28 days.

2. Samples of waste sources are taken during the survey. These will probably be a combination of composite and grab samples.

3. Sufficient receiving water samples to define profiles and distributions of substances of interest.

4. Parametric coverage will vary. However, a total assessment may require extensive coverage.

5. Biological and sediment data.

6. Physical and hydrological data.

The above examples do not represent all the types of intensive surveys nor the only purposes for conducting intensive surveys. However, they do point out that intensive studies vary, depending on their purpose. In general, a study will have to be tailored to each locality and objective. Combining the objectives of a study with others to make a multipurpose survey may prove to be a practical and economical method of scheduling and planning intensive surveys.

Survey Design

The overall success or failure of an intensive survey, with respect to its stated objectives, will be controlled to a large extent by the adequacy of the presurvey planning. Two levels of planning and scheduling are suggested for intensive surveys. The first is a yearly schedule describing the anticipated surveys, their objectives, expected duration, location, time of year during which they should be conducted, and estimated resource expenditures. The second level of planning will address each survey separately and outline the detailed requirements for the survey. The first level of planning is discussed in the planning and management section of this document; the second level will be discussed here.

The second level of planning will yield a comprehensive work plan for the survey. Included in the plan will be: Station locations, manpower and equipment requirements, parametric coverage, sampling frequencies, and work assignments for the field and laboratory crews. The survey objectives will govern a number of these items, such as station locations and parametric coverage. Implicit in the second level of planning is that all personnel (field and laboratory) associated with the survey will be thoroughly briefed on the objectives and nature of the survey.

In general, the development of a survey work plan should take the following course.

1. Desk top review of the available data on the water body under investigation. Almost all surface waters in the United States have been studied to some extent.

2. If the data from step 1 is not sufficient or if the area is unfamiliar to the survey personnel, then a field reconnaissance of the study area may be necessary. The field reconnaissance is an invaluable tool which should be used to familiarize the principal investigators with the study area, aid in the selection and siting of sampling locations, aid in the selection of sampling procedures (boat versus bridge, wading, etc.), locate potential sites for field laboratories (if needed), and provide some insight to the quality of water to be encountered through limited collection of grab samples.

3. Arrange schedules with other agencies that may be involved in the study; e.g., the U.S. Geological Survey for flow measurements.

4. From the information obtained in (1), (2), and (3), develop a field study plan.

5. To the extent that the resource expenditures and time required differ from those estimated in the first planning level, some modification of the optimal study plan may be required. If modifications are required, every effort to maintain consistency with the original study objectives should be made.

Station locations, and sampling frequencies will be two of the controlling factors in the overall study plan. Some general statements concerning these factors follow.

Station Locations. In general, station locations will be located within the survey area in such a way as to measure: (1) Inputs and diversions; (2) transformation of substances; (3) movement and distribution of substances; and (4) inputs and outputs of substances to and from the study area. Some typical station locations are as follows.

- In wastewater outfalls for measuring contributions from point sources.
- At representative sites in tributaries that feed the study area.
- Within the water body to define distributions and gradients of substances.
- At the study boundaries.

- At any fixed monitoring network station that is located within the study area.
- At locations suited for biological monitoring.
- In sediments for measuring such things as benthic oxygen uptake, pollutant concentrations, sediment transport, etc.

Sampling convenience and ease of access to the water should be considered in establishing station locations. However, they should not be considered as limiting factors. If a critical location is located several miles upstream of a bridge and not accessible by car, the station should not be moved to the bridge and data extrapolated, but the mode of sampling should be changed to boating or walking.

Sampling Frequencies. Sampling frequencies are established by the variations of the system (sources and receiving water) and the nature of the pollutants (conservative and nonconservative). Frequencies should be adequate to account for variations in the flows and quality of pollution sources, and the variations in stream flow, and tidal action. This establishes a spectrum ranging from a daily grab sample (suitable for the rare steady-state condition) to continuous collection over a suitable time period.

Operation

The study plan will control the overall conduct of the survey.

Data generation in an intensive study is subject to the quality assurance procedures (field instrument calibration, sample preservation, laboratory quality control procedures, etc.) outlined in Part VI, QUALITY ASSURANCE. Field personnel should be familiar with the appropriate quality assurance procedures.

A technical summary document (including procedures and data) should be prepared for each study. Included in the report should be a statement of the study objectives and a description of the work plan. This information will allow for independent assessments of the study and provide information upon which to base future studies.

Resources

The resource commitment for the conduct of intensive surveys is somewhat variable. The resource estimates given here are based on a capability to perform one load allocation survey per month. Many States will require a greater capability, while some may require less. Estimates for lake surveys are also included, although these surveys may also require fixed station monitoring.

The conduct of an intensive survey requires sufficient resources to design and conduct the field operations with backup support in biology, chemistry, and microbiology, including both a fixed laboratory and, if needed, a mobile laboratory or temporary remote laboratory.

The basic unit manpower for the estimates made here consist of a field party chief, three qualified technicians, a chemist, a microbiologist, and a biologist. It is assumed that the minimum sampling period would be 5 consecutive days. The basic intensive survey unit manpower estimates are shown in Table III.3.

The primary emphasis of a lake monitoring program is to establish the trophic levels and in cases where lakes exhibit eutrophic conditions to identify the causative factors. Resources for this specialized form of monitoring are reasonably well covered in the estimates for intensive surveys. The exception is that a qualified limnologist, with competency in the physical and biological aspects of lake dynamics, should be in charge of both monitoring network design and data interpretation. Also, a more intense parametric coverage for macro, and micro nutrients as well as developing an understanding of the production potential at different trophic levels is required.

Additional resources for lake monitoring include the ones listed on Table III.4.

GROUND WATER MONITORING

General

The use of ground water for public and private water supplies is steadily increasing. Concurrently with the increase of ground water use has been an increase in the pollution and contamination of ground waters. New and stringent Federal and State pollution control laws governing the disposal of wastes in the traditional manners (surface waters and air) have, in many cases, increased the attractiveness of resorting to subsurface or surface (land) disposal of waste. Because of this increasing threat to the quality of ground water and because of a general lack of comprehensive information on the origins, scope, and nature of existing ground water pollution problems, it is important that monitoring

TABLE III.3
ESTIMATED MANPOWER REQUIREMENTS FOR INTENSIVE SURVEYS

Activity	Personnel	Time (man-weeks)	Remarks
Initial planning	Field party chief* and lab personnel	2 MW	Assemble maps and post data
Reconnaissance (if needed)	Field party chief* and biologist	1 MW	Select sampling sites and synoptic biological screening
Mobilize field equipment and crew	Field party chief* technicians and lab crew	1 MW	Get all equipment together and ensure it is in working order
Field sampling	Field party chief* 2 laboratory crew 3 technicians 1 biologist	1 MW 3 MW 4 MW 1 MW	Field sample collection and field lab analyses
Fixed lab analyses chemistry and biology	Chemist Biologist	15 MW 3 MW	Assume 20 samples per day for 15 parameters, chemistry and plankton, and invertebrate identification and enumeration
Data analyses and report preparation	Field party chief* chemist and microbiologist, typist	3 MW	Analyze data, write and type report

* In the case of estuarine or near coastal studies this would be an oceanographer.

TABLE III.4
ESTIMATED MANPOWER REQUIREMENTS FOR LAKE SURVEYS

Activity	Personnel	Time (man-weeks)	Remarks
Network design	Principal limnologist	1 MW	Review historical data and establish stations
Fixed station sampling	Field limnologist and technician		Time dependent on number of stations and mode of transportation
Intensive survey	Full field crew and limnological guidance		
Fixed laboratory analyses	100 analyses per week—lab members		
Data interpretation and report			

programs be established and maintained to monitor ground water quality. A ground water monitoring program should reflect the needs of the ground water management program.

Purposes

The overall objectives of the ground water monitoring program are as follows.

- To obtain data for the purpose of determining baseline conditions in ground water quality and quantity.
- To provide data for the early detection of ground water pollution or contamination, particularly in areas of ground water use.
- To identify existing and potential ground water pollution sources and to maintain surveillance of these sources, in terms of their impact on ground water quality.
- To provide a data base upon which management and policy decisions can be made concerning the surface and subsurface disposal of wastes and the management of ground water resources.

Network Design

Within the context of a model program, it will be assumed that the ground water monitoring effort will be a joint effort among the State and Federal agencies concerned with well drilling, geology, water resources, public health, ground water, etc. No attempt will be made to outline the administrative responsibilities of the program. Only the functional aspects of the program will be discussed.

The design of a ground water monitoring network requires a knowledge of the following.

- The physical, chemical, and biological characteristics of the pollutants that are known or suspected of entering the ground waters.
- The physical and chemical characteristics of the aquifer(s) of interest, including mineralogy and natural water quality.
- The pattern and rate of movement of ground water in the aquifer(s) of interest.
- Present and intended uses of the ground water resource.

In the process of network design this information may be used to predict the course of pollution. These predictions can then be used for locating sampling locations.

The compilation of the above data will involve the utilization of available information for the purposes of:

1. Identifying and describing the principal aquifers within the State.
2. Describing and defining known geological or hydrogeological structures that could affect water quality. Included in this data should be information on wells which have been plugged or abandoned and represent actual or potential pollution sources, such as oil and gas wells.
3. Identifying areas where geological or hydrogeological data are lacking and initiating efforts to obtain the required data.
4. Developing an inventory of actual or potential ground water pollution sources. This inventory should include consideration of the following.
   a. Landfills and open dumps.
   b. Holding ponds and waste disposal pits.
   c. Municipal and industrial waste lagoons.
   d. Chemical stockpiles.
   e. Fuel tank farms.
   f. Injection wells for waste disposal.
   g. Feedlots.
   h. Areas of known or suspected saltwater intrusion.
5. Developing an inventory of existing or potential ground water quality monitoring wells. The inventory should include information from well drilling logs and a description of the length and location of the well casing and screens. This inventory may include the following information.
   a. Drinking water supply wells.
   b. Irrigation wells.
   c. Injection site monitoring wells.
   d. Wells for monitoring saltwater intrusion.
6. Evaluating existing well water quality data.

The above inventories and information should provide the basic information upon which a monitoring network can be designed. The effective maintenance of a monitoring program will require that the above information be updated and evaluated on a regular basis.

Station siting is perhaps the most difficult step in establishing a ground water monitoring system. One of the most important factors in assessing the need for monitoring in an area will be the probability of pollution or contamination and the associated hazards of the pollutants or contaminants. A monitoring network should have stations that:

- Provide data that can be used to establish baselines in quality and detect trends in the water quality of principal aquifers. The data from these stations may become part of the data base upon which management and policy decisions are based, particularly in the area of new pollution sources and their control. Generally, a true representation of an entire aquifer cannot be achieved due to the inherent heterogeneities in aquifers. Therefore, representative sampling will probably be limited to those portions of aquifers which are significant with respect to ground water use and pollution.

- Are located in areas of high utilization of ground water, such as drinking water supply areas. These stations will be used to evaluate the ground water quality with respect to its suitability for use. Degradation or improvement of water quality should be correlated with other monitoring data and inventories to form a data base for effective ground water management.

- Are located at representative points relative to ground water pollution sources. These stations will provide data for the characterization of different types of sources with respect to their impact on ground water quality and for early detection of pollution.

The exact location and number of ground water monitoring stations will be governed by the nature and degree of ground water use and the distribution of actual or potential pollution sources. Existing wells should be used, when possible, for monitoring purposes. However, it may also be necessary to establish new wells to provide adequate coverage.

Network Operation

The substances to be measured at ground water monitoring stations will vary with the natural and manmade conditions and with the use of ground water. The inventory of pollution sources will help to determine the parameters to be measured. Some examples of pollution sources and their associated pollutants are:

- Saltwater intrusion: High dissolved solids, particularly sodium and chlorides.

- Industrial lagoons: Heavy metals, acids, solvents, and other inorganic and organic substances.

- Cesspools, septic tanks, and sewage effluent lagoons: High dissolved solids, chlorides, sulfates, nitrogen, phosphates, detergents, and bacteria.

- Tank farms, refineries for gasoline, fuel oil, solvents, and other petroleum related chemicals: Phenols, suspended solids, oil & grease, chromium, sulfide, pH, ammonia, BOD, COD, TOC.

- Landfills and dumps: Soluble organics, iron, manganese, methane, carbon dioxide, nitrogen, phosphates.

- Stockpiles of chemical materials: Heavy metals, salts, other organic and inorganic chemicals, and high dissolved solids.

The sampling frequency for ground water monitoring stations will also be controlled by local conditions. The proximity of pollution sources to aquifers and areas of water use and the rate of water movement within the aquifers will probably be the two most important factors in determining an adequate sampling frequency.

All sampling should be done by trained personnel with a knowledge of the various methods of well sampling and in-place measurements. Sample preservation and laboratory analyses should be performed in accordance with the procedures outlined in Part VI, QUALITY ASSURANCE.

Resources

The resource estimates made here are based on performing the following activities.

1. Identifying and describing principal aquifers.

2. Describing the geological and hydrogeological structures of principal aquifers.
3. Developing inventories of existing monitoring wells and potential or actual pollution sources.
4. Evaluating existing data.
5. Designing the ground water monitoring network.
6. Arranging for sample collection, using either agency personnel and/or cooperators.
7. Providing the primary laboratory support and coordinating efforts to continue the monitoring program.
8. Providing data analysis and summarizations to show baselines, trends, problem areas, and to identify areas in need of further study.

Table III.5 gives the manpower estimates for maintaining a ground water monitoring program.

TABLE III.5
MANPOWER ESTIMATES FOR GROUND WATER MONITORING

Item	Personnel	Time	Remarks
System design and operation	Program chief and secretary	Full time	
Sample collection	Technician	Full time per 300 wells	Collects samples. Trains cooperators and furnishes holding and shipping containers. Maintains sample log. Assume annual well sampling.
Laboratory analysis	Chemist and technicians	1 man-week/100 analyses	Assume 80 analyses per year per well. 20 Quality Control.
Data compilation and analyses	Program chief and statistical staff	1 man day per well year record	
Location and logging existing and new pollution sources	Engineer	Full time	

REFERENCES

Listed below are some general literature references for each of the three monitoring activities discussed in this section. The references given are not all of the available information on monitoring. However, a review of the listed references should be useful in establishing a basic knowledge of the subject matter.

Fixed Monitoring Networks and Intensive Surveys

1. Federal Water Quality Administration, Design of Water Quality Surveillance Systems, Cyrus W. M. Rice Division, NUS Corporation, Contract No. 14–12–476, August 1970.
2. Kittrell, F. W., A Practical Guide to Water Quality Studies of Streams, U.S. Department of the Interior, Federal Water Pollution Control Administration.
3. Mackenthun, K. M., Toward A Cleaner Aquatic Environment, Environmental Protection Agency, Office of Air and Water Programs, 1973.
4. Mackenthun, K. M., The Practice of Water Pollution Biology, U.S. Department of the Interior, Federal Water Pollution Control Administration, 1969.
5. Proceedings of the National Symposium on Estuarine Pollution, Sponsored by: The American Society of Civil Engineers and Stanford University, Stanford, California, August 1967.
6. U.S. Environmental Protection Agency, Handbook for Monitoring Industrial Wastewater, August 1973.
7. U.S. Environmental Protection Agency, Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants, May 1972.
8. U.S. Environmental Protection Agency, Water Quality Studies, Training Manual, Water Quality Office, March 1971.

Ground Water Monitoring

9. Charles E. Pound, Rondal W. Criter, Wastewater Treatment and Reuse by Land Application, Metcalf and Eddy Inc., Environmental Protection Agency, Office of Research and Development, Contract No. 68–01–0741, May 1973.
10. Groundwater Pollution From Subsurface Excavations, U.S. Environmental Protection Agency, Office of Air and Water Programs, Water Quality and Nonpoint Source Control Division, 1973.
11. H. E. Legrand, Patterns of Contaminated Zones of Water in the Ground, Water Resources Research, American Geophysical Union, Volume 1—First Quarter, Number 1, 1965.
12. R. J. Pickering, Robert W. Maclay, Steps Toward Design of Systems for Monitoring Groundwater Quality, U.S. Geological Survey, Washington, D.C., Presented at the 106th National Meeting of the American Chemical Society, Chicago, Ill., September 1970.
13. Well Water Journal, The Authoritative Primer-Ground Water Pollution, Special Issue, July 1970.

Data Interpretation

14. Federal Water Pollution Control Administration, Data Evaluation and Analysis, Training Manual, December 1969.
15. U.S. Environmental Protection Agency, Simplified Mathematical Modeling of Water Quality, Hydroscience, Inc., Division of Water Quality Standards and Planning, March 1971.

PART IV
BIOLOGICAL MONITORING

INTRODUCTION

Biological monitoring is receiving increased attention with passage of the recent Federal legislation. This change is principally due to the fact that biological data is organism-dependent and can give the surest knowledge of effects of pollution.

Aquatic organisms and communities act as natural pollution monitors. When an aquatic community undergoes a stress (pollution), the community structure is affected. For monitoring purposes, this effect can be long term and can be detected, measured, and analyzed. Since aquatic organisms respond to their *total* environment and since this response is not short lived, they can often provide a better assessment of stream quality and environmental damage, than can other monitoring methods. Some organisms tend to accumulate or magnify toxic substances, pesticides, radionuclides, and a variety of other pollutants. Organisms also can reflect the synergistic and antagonistic interactions of point and nonpoint source pollutants within the receiving water system.

In order to properly assess pollution and determine corrective actions, it is essential that the pertinent scientific and nonscientific disciplines work in concert. Many times, the taxonomic complexity and the use of Latin terms veil the importance of biological data to the nonbiologist; yet valid water assessment is sometimes impossible without biological data.

In biological studies, perhaps more than in any other single area of water quality studies, the reliability of study results and data interpretation depend on the experience and judgment of the staff involved. Such studies to be of full use to the planning, enforcement, and management of a State water pollution abatement program, should be multidisciplinary.

Because of the complex nature of biological studies, the staffing guides and other materials in this section are somewhat more detailed than elsewhere.

OBJECTIVES

The objectives of a biological monitoring program are to gather biological data in such a manner as to:

- Determine suitability of aquatic environments for supporting abundant, useful, and diverse communities of aquatic organisms.
- Provide information adequate to detect, evaluate, and characterize changes in water quality through the study of biological productivity, diversity, and stability of aquatic systems.
- Detect presence and buildup of toxic and potentially hazardous substances in aquatic biota.
- Provide information adequate to periodically update the eutrophic condition classification of freshwater lakes.

Such a program should include the following.

Intensive Surveys. The results obtained from the biological analyses will be combined with water quality data results and thoroughly studied before final assessment is made.

Long-Term (Trend) Monitoring. Long-term trends should be determined in part from the results of statistical and subjective evaluation of the biological data.

Toxic Materials Monitoring. The detection and analysis of toxic substances, radionuclides, pesticides, heavy metals and any other potentially hazardous pollutant that will be picked up and assimilated by a number of different organisms and magnified through the aquatic food web.

Eutrophic Condition Monitoring. Classification of freshwater lentic environments according to trophic condition.

For purposes of biological monitoring, a station will normally encompass areas, rather than points, within a reach of river or area of lake, reservoir, or estuary adequate to represent a variety of habitats typically present in the body of water being monitored. Unless there is a specific need to evaluate the effects of a physical structure, it will normally be advisable to avoid areas which have been altered by a bridge, weir, within a discharge plume, etc. Thus, biological sampling stations may not always coincide with chemical or sediment stations.

STRATEGY

Trend Monitoring

A system of long-term biological monitoring stations should be established as follows.

1. At key locations in water bodies which are of critical value for sensitive uses such as domestic water supply, recreation, propagation, and maintenance of fish and wildlife.

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2. In major impoundments near the mouths of major tributaries.
3. Near the mouths of major rivers where they enter an estuary.
4. At locations in major water bodies potentially subject to inputs of contaminants from areas of concentrated urban, industrial, or agricultural use.
5. At key locations in water bodies largely unaffected by man's activities.

Intensive Surveys

Periodic intensive surveys should be conducted in the following situations.

1. In major water bodies having high or potentially high public water use values from the standpoint of water supply, recreation, propagation, and maintenance of fish and wildlife.
2. To determine cause and effect relationships in water bodies where long-term (trend) monitoring reflects a deterioration in environmental quality.
3. To provide data on damage in situations where compliance monitoring indicates violations of permits and/or water quality standards.

Toxic Materials Monitoring

Uptake and concentration by the biota of toxic and potentially hazardous substances should be studied at key long-term biological monitoring stations established as discussed in Part III, AMBIENT WATER QUALITY MONITORING.

PARAMETERS

Trend Monitoring

Priority 1 parameters listed in Table IV.1.

Intensive Surveys

Priority 1 and 2 items listed in Table IV.1.

Toxic Materials Monitoring

Chemical analyses of representative whole finfish and/or shellfish at selected stations.

SAMPLING FREQUENCY AND REPLICATION

Recommended sampling frequency for various parameters should conform as closely as possible to those shown in Table IV.1.

Sections of the EPA Biological Field and Laboratory Methods provide guidelines concerning sample replication. The following are suggested as minimum levels for various parameters. If resources are available, these minimums should be increased.

Plankton Grab Samples

1. Trend Monitoring—Three near-surface grabs.
2. Intensive Surveys
   a. Standing waters—Three near-surface grabs, three at 50-percent light extinction, and three at 1-percent light level.
   b. Flowing waters—Three near-surface grabs.

Periphyton

1. Trend Monitoring—Four replicate slides per station for counts and identification.
2. Intensive Surveys—Four replicates each for counts, chlorophyll a, and biomass. (Chlorophyll a and biomass can be obtained from the same slide.)

Macrophyton

1. Trend Monitoring—Prepare maps showing areal coverage by major species and species associations in vicinity of sampling stations.
2. Intensive Surveys—Same as above plus four random samples for biomass determination from a randomly selected quadrant in each vegetative habitat type mapped.

Macroinvertebrates

1. Trend Monitoring—Four replicate artificial substrates per station.
2. Intensive Surveys—Same as trend monitoring plus four replicate samples using an appropriate grab in each major substrate type. For flesh tainting (where commercially valuable shellfish are present) and toxic substance analysis, collect three specimens of one or more species of shellfish (crustaceans and/or bivalves).

Fish

1. Trend Monitoring—A minimum of four specimens of a major piscivore at each station for chemical analysis.

TABLE IV.1

BIOLOGICAL MONITORING

Community	Parameter	Priority *	Collection & Analysis Method **	Sampling Frequency ***
Plankton	Counts and identification;	1	Grab samples	Once each—in spring, summer and fall
	Chlorophyll *a*;	2		
	Biomass as ash-free weight.			
Periphyton	Counts and identification;	1	Artificial substrates	Minimally once annually during periods of peak periphyton population density and/or diversity.
	Chlorophyll *a*;	2		
	Biomass as ash-free weight;	2		
Macrophyton	Areal coverage;	2	As circumstances prescribe	Minimally once annually during periods of peak macrophyton population density and/or diversity.
	Identification;	2		
	Biomass as ash-free weight.	2		
Macroinvertebrate	Counts and identification;	1	Artificial and natural substrates	Once annually during periods of peak macroinvertebrate population density and/or diversity.
	Biomass as ash-free weight.	2		
	Flesh tainting;	2		
	Toxic substances in tissue.****	2		
Fish	Toxic substances in tissue; ****	1	Electrofishing or netting	Once annually during spawning runs or other times of peak fish population density and/or diversity.
	Counts and identification;	2		
	Biomass as wet weight;	2		
	Condition factor;	2		
	Flesh tainting	2		
	Age and growth.	2		

* Priority.
1—Minimum Program.
2—Add as soon as capability can be developed.

** See EPA Biological Methods Manual.

*** Keyed to dynamics of community.

**** See Analysis of Pesticide Residues in Human and Environmental Samples, "USEPA, Perrine Primate Research Laboratories, Perrine, Florida 32157 (1970)," and "Pesticide Analytical Manual," USDHEW, FDA, Washington, D.C.

2. Intensive Surveys—Same as above plus four 30-minute units of electrofishing effort during both daytime and nighttime (total of eight 30-minute units of effort). If electrofishing methods are not appropriate, then suitable netting or trapping gear should be used. Because of gear selectivity, if time and resources are available, a variety of sampling gear should be used.

QUALITY ASSURANCE

Refer to Part VI, QUALITY ASSURANCE.

DATA PRESENTATION

For the parameters of biological communities shown in Table IV.2, the mean and standard deviation should be presented in tabular form (Mackenthun, 73). When more than 1 year of data are obtained at long-term stations, then trends should be shown pictorially by a suitable technique, such as bar graphs.

EUTROPHIC CONDITION MONITORING

There is likely no single parameter or group of parameters that will serve as a universal mechanism to detect changes in the trophic status of all the diverse types of freshwater lentic environments in the U.S. Nevertheless, by a careful establishment of criteria, it is possible to derive a list of parameters which can be practicably measured and which have adequate sensitivity to provide meaningful assessments. In selecting parameters, it should be kept in mind that the primary objective in trophic condition monitoring is to detect change, not cause and effect relationships. The following criteria were utilized in selecting parameters shown in Table IV.3. Table IV.4 gives an example of some parametric values which can serve as criteria for determining trophic status. The National Eutrophication Survey, being conducted by EPA's National Environmental Research Center in Las Vegas, is presently involved in the search for "standard" indexes with which to quantify trophic conditions.

Redundancy. Parameters should not be selected that are closely related and/or correlated in such a manner that they provide similar information (e.g., conductivity, hardness, dissolved solids, and alkalinity). In such a case, select the parameter most simply and inexpensively measured.

Fluctuation. Parameters that are subject to severe hourly, daily, and/or seasonal fluctuation (i.e., lack stability) should be avoided or subject to very careful interpretation.

Integration. Parameters whose level is a function of the interacting effects of several physical, chemical, and biological factors are highly desirable.

Sensitivity. Parameters should be sensitive to subtle perturbations of the system.

Cost. Parameters should be simple and inexpensive to measure.

In addition to the above criteria, a minimum number of parameters must be selected which provide a means of simple classification of lake types so that other parameters may be more meaningfully assessed. Some of these parameters (such as mean depth) may only have to be measured infrequently.

RESOURCES

Staffing

1. Areas of Expertise
   a. Critical.
      (1) Aquatic Botanist.
         (a) Plankton analyses.
            Phytoplankton Sedgewick-Rafter count and identification.
            Diatom species proportional count.
            Biomass and chlorophyll analysis.
            Algal assay.
         (b) Periphyton analyses.
            Algae, bacteria, etc., cell count, and identification.
            Diatom species proportional count and identification.
            Biomass and chlorophyll analysis.
         (c) Macrophyton.
            Identification.
            Areal coverage.
            Biomass and chlorophyll analysis.
      (2) Macroinvertebrate Specialist (freshwater).
         (a) Collection.
         (b) Identification.
         (c) Numerical and biomass analysis.
      (3) Macroinvertebrate Specialist (marine) (for coastal States).
         (a) Collection.

TABLE IV.2
PARAMETERS OF BIOLOGICAL COMMUNITIES

Community	Parameter	Units
Plankton	Counts	Numbers/ml by genus and/or species
	Chlorophyll *a*	mg/m^3
	Biomass (ash-free dry weight)	mg/m^3
Periphyton	Counts	$Numbers/mm^2$
	Chlorophyll *a*	mg/m^3
	Biomass (ash-free weight)	mg/m^2
	Autotrophic index	$\frac{\text{Ash-free weight } (mg/m^3)}{\text{Chlorophyll } a \ (mg/m^3)}$
Macrophyton	Areal coverage	Maps by species and species associations
	Biomass (ash-free weight)	g/m^3
Macroinvertebrate	Counts	Grab — number/m^3 Substrate — number/sampler
	Biomass	g/m^3
	Toxic substances	mg/kg
Fish	Toxic substances	mg/kg
	Counts	Number/unit of effort, expressed as per shocker hour or per 100 feet of a 24-hour net set
	Biomass (wet weight)	Same as counts
	Condition	$K(TL) = \frac{10^5 \times \text{weight in grams}}{L^3 \text{ (length in mm)}}$

TABLE IV.3

PARAMETERS FOR EVALUATING CHANGES IN TROPHIC CONDITION

Parameter	Frequency of measurement	Priority*	Comments
PHYSICAL			
Temperature profile	Once annually—midsummer	2	To determine if lake is thermally stratified
Mean depth	Once every 5–10 years	2	For classification purposes
Conductivity	Once annually—midsummer	1	As a function of TDS, alkalinity, and hardness; this is a measure of potential
Color	Once annually	2	For classification
Secchi disc transparency	Once annually—midsummer	1	Function of suspended solids, color, and biological growths
CHEMICAL			
DO profile	Once annually—midsummer	1	Should be done in mid-afternoon
Sediment volatile solids	Once annually	1	Measure of organic character of sediments. Express as percent by weight
Total N	Once annually—midsummer	2	Helps establish cause and effect relationships
Total PO_4 (as P)	Once annually—midsummer	2	Helps establish cause and effect relationships
BIOLOGICAL			
Plankton algal diversity	Once annually—midsummer	1	
Seston ash-free	Once annually—midsummer	1	Near-surface sample
Chlorophyll *a*	Once annually	1	Sometimes correlated with bio-seston biomass
Periphyton biomass on slides	Midsummer—2-week exposure	1	
Macrophytes—percent surface coverage	Early summer	1	
Algal assay	Once annually—midsummer	1	

* Priority 1 parameters meet all of the five criteria listed and have maximum utility in assessing changes in trophic status. Priority 2 parameters do not meet all criteria but may have utility in certain situations or may be useful in evaluating cause and effect relationships and/or management needs.

TABLE IV.4

SUGGESTED PARAMETRIC CRITERIA FOR DETERMINING TROPHIC STATUS OF LAKES

Plankton parameter	Trophic status		
	Oligotrophic	Mesotrophic	Eutrophic
Algae/ml	0–2,000	2,000–15,000	15,000
Chlorophyll (mg/m^3)	0–3	3–20	20
Primary production ($gc/m^2/day$)	0–0.2	0.2–0.75	0.75
Biomass (mg/1)	0–1	1–10	10
Cell volume ($mm^3/1$)	0–5	5–30	30
Rotifers/liter	0–10	10–250	250
Microcrustacea/liter	0–1	1–25	25
Species diversity	low	high	low

(b) Identification.
(c) Numerical and biomass analysis.

(4) Fishery Biologist.
(a) Sampling and identification.
(b) Growth and condition.
(c) Flesh taste and odor studies.
(d) Bioassay.
(e) Fish kills.

b. Desirable.

(1) Aquatic Microinvertebrate Zoologist.
(a) Zooplankton counts and identification.
(b) Periphyton counts and identification.

(2) Fish Histopathologist.
(a) Fish kill investigation.
(b) Bioassay.

(3) Plant Physiologist (metabolic studies).
(a) Plant production and respiration.
(b) Benthic respiration.

2. Minimum Types of Expertise Required

a. To conduct complete biological sampling programs a staff having the following specializations will be needed.

(1) Aquatic Botanist.

(2) Macroinvertebrate Specialists.
(a) Freshwater.
(b) Marine (for coastal States).

(3) Fishery Biologist.

b. The number of these specialists required will depend on size of the program. Assuming full-time assignment to monitoring activities, a responsible program with 50 trend stations and four intensive surveys a year would, on the minimum, require:

(1) Aquatic Botanists.
(a) Taxonomic specialist—1.
(b) Metabolic specialist—1.

(2) Macroinvertebrate Specialists.
(a) Freshwater—2.
(b) Marine (if needed)—1.

(3) Fishery Biologist—1.

(4) Technicians—3–4.

A total of five professionals (six in coastal States) and three to four technicians are needed to conduct a responsible monitoring program. The technicians are needed for assisting in the field work and to perform routine functions in the laboratory.

3. Training and Experience Desired

a. Aquatic Botanist.

(1) Phytoplankton and periphyton Sedgwick-Rafter counts and identification.

(a) Training desired:
Formal training—Bachelor's Degree in biology, with courses in phycology, plant physiology, and plant ecology.
In-service training—Specialized training in algal taxonomy and ecology.

(b) Experience desired to reach an acceptable level of performance—1 year.

(2) Diatom species proportional count and identification.

(a) Training desired:
Formal training—Bachelor's degree in biology, with course in diatom identification.
In-service training—Specialized training in diatom taxonomy and ecology.

(b) Experience desired to reach an acceptable level of performance—2 years.

(3) Macrophyton identification.

(a) Training desired:
Formal training—Bachelor's degree in biology, with courses in vascular plant taxonomy and ecology.
In-service training—Specialized training in aquatic plant taxonomy and ecology.

(b) Experience desired to reach an acceptable level of performance—1 year.

(4) Biomass and chlorophyll.

(a) Training desired:
Formal training—Bachelor's degree in biology, with courses in plant physiology and general organic chemistry.
In-service training—Pigment analysis by spectrophotometric and fluorometric techniques.

(b) Experience desired to reach an acceptable level of performance—6 months.

b. Aquatic Microinvertebrate Zoologist (zooplankton and periphyton analyses).

(1) Training desired:
Formal training—Bachelor's degree in biology, with courses in protozoa, rotifer, cladocera, and copepoda taxonomy and ecology.

In-service training—Specialized training in protozoa, rotifer, cladocera, and copepoda taxonomy and ecology.

(2) Experience desired to reach an acceptable level of performance—2 years.

c. Macroinvertebrate Specialist.

(1) Training desired:
Formal training—Bachelor's degree in biology with courses in taxonomy and invertebrate zoology.
In-service training—Experience in sampling and analysis of benthic samples and taxonomy.

(2) Experience desired to reach acceptable level of performance—1 year.

d. Fishery Biologist.

(1) Training desired:
Formal training—Bachelor's degree in biology with course work in ichthyology, fishery biology, and limnology.
In-service training—Experience in sampling and analysis of fish samples.

(2) Experience desired to reach acceptable level of performance—1 year.

Space and Equipment

1. Space

a. Storage of field equipment (boat, motor sampling equipment, etc.) requires a garage type enclosure of at least 400 square feet.

b. Laboratory analysis (sample preparation, counting, identification, bioassay, etc.) requires at least 1200 square feet.

c. Sample storage area within the lab requires an area of no less than 400 square feet.

2. Equipment

For an abbreviated list of equipment and supplies used for the collection and analysis of biological samples and their approximate costs (Mackenthun, 73).

Data Storage and Retrieval

If the size of the monitoring program necessitates the use of a computerized system, an information system should be used that is capable of making biological data readily available and easily accessible to the user population within a required time frame.

Water quality data validation and edit routines are essential to maintain quality control. The system should also provide standardized processing tools to facilitate data manipulation and interpretation.

For more information concerning data handling refer to Part II, PLANNING AND MANAGEMENT.

DATA INTERPRETATION

The purpose of this section is not to recommend one particular data evaluation method, but to point out a number of more common methods. Some of these methods may not be applicable to each stream or water body in the United States.

Water quality is reflected in the species composition and diversity, population density, and physiological condition of indigenous communities of aquatic organisms (Weber, 73). A number of data interpretation methods have been developed based on these community characteristics to indicate the degree of water quality degradation, and also to simplify communication problems regarding management decisions.

These methods can be categorized within four basic subject areas: Presence and/or absence of specific indicator organisms; community diversity; bioaccumulation studies; eutrophication-lake classification; and other methods.

Presence and/or Absence of Specific Indicator Organisms

This system is usually based upon a classification of organisms as either pollution sensitive (intolerant), facultative (variable), or tolerant. For example, usually stoneflies, mayflies, and caddisflies are considered sensitive or facultative and, therefore, are usually the first to suffer in a polluted environment. Sludgeworms and bloodworms, on the other hand, can tolerate very heavy pollutional loads.

A classic example of a system using the presence/absence criteria, is the Saprobien system which recognizes three basic zones of pollution ranging from a zone of heavy pollution (polysaprobic) characterized by a lack of dissolved oxygen, an abundance of bacteria, and the presence of a few tolerant species, to a zone of recovery (oligosaprobic) characterized by relatively pure water with a somewhat stable species diversity and dissolved oxygen concentration. This system is widely used in Europe but its usefulness is limited to organic pollutants in slow moving streams and is not always applicable to rivers and streams of the United States.

Some Americans have tried to modify the Saprobien system. Wilber, in The Biological Aspects of Water Pollution, 1969, classifies stream segments as follows.

- A clean stream—one with clean water, containing many varieties of fishes and weeds and aquatic organisms.
- A zone of degradation—the zone into which waste material is discharged. Dissolved oxygen is low in amount the water tends to be turbid; many aquatic organisms disappear. So-called sport fish are replaced by "rough" fish. Slimy growth of fungi appears, deposition of sludge on the bottom.
- A zone of active decomposition—natural process of purification begins. Usually, no fishes of any sort; dissolved oxygen about zero, water dark in color, offensive in odor, large amounts of sludge on the bottom, and gas bubbles may be seen rising to the surface.
- A zone of recovery—the effect of the natural recovery process are first seen here. Increase in amount of dissolved oxygen, turbidity decreasing, a few fish, little or no sludge on the bottom.
- A clean stream—the water has been returned to its clean natural condition. The sizes of the several zones and their distance from the area where the pollution material was introduced into the stream will vary with factors such as volume and rate of flow of the stream, temperature of the water, time of year, and other local factors.

This approach is highly subjective and would naturally vary from one stream to another. It is also restricted to organic-type wastes.

Community Diversity

This involves the development of biotic indexes based on the relative impact of stress (pollution) on the species diversity, the total number of organisms and redundancy or the dominance of organisms in each species population within the aquatic community. EPA procedures regarding quantitative data interpretation using diversity indexes are discussed in the EPA "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents" in the macroinvertebrate section.

Bioaccumulation Studies

These methods apply in the detection and analysis of toxic substances, radionuclides, heavy metals, pesticides, and any other potentially hazardous pollutants that can be assimilated by a number of different organisms and concentrated through the food chain. Studies are conducted using various populations of organisms from the algae through the macroinvertebrates to the fish. Studies may be centered on the organism as a whole or perhaps on an individual organ within the organism.

Eutrophication—Lake Classification

A fourth method of water quality assessment or classification pertains to lake eutrophication.

A number of different sets of criteria have been developed to ascertain the degree of eutrophication. The only agreement seems to be in the nomenclature used: (oligotrophic, mesotrophic, and eutrophic). The National Eutrophication Survey is continually searching for better methods with which to quantify lake trophic conditions.

It should be noted that biological monitoring does not replace chemical or physical monitoring. These monitoring activities are supplemental to each other, and should be mutually supportive. It is

difficult for any discipline to translate the knowledge it has accrued and the data it has obtained to the language of another discipline without losing something in the translation. However, through the use of certain statistical methods, sets of criteria, or analytical methods biological data can be better understood. The criteria that these biological methods are based upon are not foolproof. For example, the breakdown of an assemblage of organisms into pollution tolerant, intolerant, and facultative is somewhat subjective for the same organisms may vary under a different set of environmental conditions. Therefore, the concept of the use of "indicator" organisms to evaluate biological water quality can present real difficulties. Every stream is different and complex data interpretation requires a qualified biologist.

Other Methods

A number of other methods deserve mention.

Beck's Biotic Index. Beck (1955) devised the first really simple method of illustrating biological data in an easily understood form. This method divides certain organisms (the organisms chosen are indigenous to the State of Florida and, therefore, may not be applicable to the rest of the country) into two categories:

Class I—Those which can tolerate no significant amounts of pollution.

Class II—those which can tolerate moderate organic pollution, but disappear in conditions which are anaerobic or nearly so.

In computing the index more weight is given to Class I organisms because they are the least tolerant of pollution.

This index has proven useful in the Florida region, but does not take into account the relative abundance of individuals of different species nor the presence of most of the species in the community.

Wilhm's Species Diversity Index (Wilhm, Dorris, 1968). This index is based upon information theory and is an attempt to give a numerical value to the environmental changes caused by waste dischargers. This index takes into account not only the number of species encountered, but also the relative abundances of the different species. Results from this system indicate that values of d less than one are indicative of heavy pollution, values from one to three indicate moderate pollution and values above three are found in clean water areas.

The Sequential Comparison Index (SCI) (Cairns 1968). This index is a simplified method for estimating relative differences in biological diversity. It was developed to fill the need for a rapid numerical method of assessing the biological consequences of pollution. The SCI is an expression of community structure since it is dependent not only upon the compositional richness of the community, but also upon the distribution of individuals among the taxa. In this technique, similar organisms encountered sequentially are grouped into "runs." The greater the number of "runs" per number of specimens examined, the greater the biological diversity. A numerical diversity index, DI, can be calculated for each community and statistically analyzed.

Harkins and Austin (1973) have also developed a method that appears to be universal in scope and has worked well in diverse situations. This method is based on average diversity per individual and redundancy which are reduced to a single index value per sample utilizing a nonparametric discrimination technique which then gives a unique distance value from a predefined "biological desert" condition (control values). This condition exists as the case of no organisms present or only one species containing n organisms.

Computer programs have been written to perform the needed calculations as well as the analysis of variance which can be used with this method.

Harkin's and Austin's method then is essentially an objective method for reducing several biological indexes to a single meaningful value that will reflect subtle changes in the structure of aquatic communities. The resulting sets of standardized distance values can be compared subjectively or can be subjected to statistical evaluation and probability level of differences assessed. With this method any changes of quality will be detected and can be plotted for long-term trend analysis.

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PART V
COMPLIANCE MONITORING

INTRODUCTION

This part describes a compliance monitoring program for those States which operate or intend to operate a National Pollutant Discharge Elimination System (NPDES) program and to provide advice to other States. Generally compliance monitoring data is used in support of enforcement. Such data can be used along with other information as useful inputs to certain planning and water quality control processes. In the following, the elements of a compliance monitoring program, which can be applied to the NPDES system, are described in some detail. The same general approach can also be used to accomplish other aims of compliance monitoring programs.

This Model State Compliance Monitoring Program description recommends procedures to determine compliance with NPDES permits and compliance where water quality standards apply, to validate self-monitoring reports, and as necessary to provide technical support for enforcement actions.

COMPONENTS OF A STATE COMPLIANCE MONITORING PROGRAM

The components of a State Compliance Monitoring Program are:

- Application verification.
- Plant process verification.
- Compliance schedule monitoring.
- Monitoring of compliance with permit conditions.
- Documentation of violations of toxic pollutants standards (Sec. 307(a) of PL 92–500).
- Evaluation of compliance with pretreatment standards (Sec. 307 (b) of PL 92–500).
- Documentation of emergency powers cases (Sec. 504 of PL 92–500).
- Identifying nonfilers.

Visits to major dischargers are required at least annually. Minor dischargers may be visited randomly as little as once during the term of the permit. Some visits may be only visual or qualitative and not require sampling. In other cases a quantitative inspection where samples are collected and analyzed may be necessary, particularly when there are suspected violations or when a case is being prepared for enforcement.

A minimal qualitative visit should include review of:

1. The permit.
2. Self-monitoring data.
3. Spill Prevention Control and Countermeasure Plan implementation, if appropriate.
4. Laboratory analysis techniques, if applicable.
5. Field, sample transport, and preservation, and laboratory quality control procedures, if applicable.
6. Data handling procedures.
7. Compliance with implementation schedules.

A quantitative inspection should consist of all of the above elements, plus the sampling and analysis of effluents and the process stream, as stipulated in the applicable permit or as otherwise needed. It may be appropriate in the case of some industries to sample or inspect production processes. In some municipal and industrial inspections it will be necessary to sample the plant's influent in addition to the effluent.

Recommended procedures relative to each compliance monitoring component are discussed below.

Application Verification. Application verification is the examination of applications for new or renewed permits. It includes:

1. Verification of information supplied by applicants.
2. Assuring correction of identified errors in the application.

Plant Process Verification. Plant process verification is the periodic verification that processes raw materials, water usage, waste treatment processes, production rate, and other factors relative to concentrations and loads of pollutants contained in discharges are substantially as described in the permit application and the issued permit.

It also may include determining that pollutants removed from wastewaters are not being allowed to enter navigable waters and that preparations have been made for controlling waste discharges in the event of power failure.

Compliance Schedule Monitoring. Compliance schedule monitoring is the review and evaluation of progress toward scheduled pollution control measures

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as set forth in the permit. Evaluation is based on data supplied in progress reports submitted by the applicant and through facilities inspections.

Monitoring of Compliance With Permit Conditions. Monitoring of compliance with permit conditions is the collection and evaluation of data required to show whether pollutant concentrations and loads contained in permitted discharges are in compliance with the limits specified in the permit. Such monitoring includes the following.

- The self-monitoring reports from the permittee should generally serve to flag apparent violations on effluent characteristics. When these reports are received from the permittee they should first be reviewed for completeness and for violations. If no violations are reported and the report appears to be in order, the report may be processed for automatic and/or manual data storage. Apparent violations should be reported to the appropriate enforcement authority.

- Self-monitoring verification is the periodic verification that self-monitoring is being properly executed and reported. This includes sampling, flow measurement, plant inspection, and records review and is usually, but not always, conducted with prior notice to the permittee. Self-monitoring verification generally should be conducted at least yearly at principal discharge sites, but may be conducted anytime upon receipt of information indicating possible violations. Consultation and advice to the permittee concerning proper techniques or methods may be a good approach to achieving compliance with permit conditions in a minimum amount of time.

- Case preparation monitoring includes process stream sampling, flow measurement, plant inspection, records review, and where State statutes require, development of supportive stream quality evidence. All case preparation monitoring should be performed with adequate chain-of-custody procedures. Case preparation monitoring should be carried out according to need with priorities as follows.

  a. Dischargers with unsatisfactory effluents causing obvious water quality degradation.

  b. Dischargers with unsatisfactory discharges causing marginal water quality degradation.

  c. Dischargers with unsatisfactory discharges causing little or no obvious water quality degradation.

  d. Other dischargers.

Documentation of Violations of the Toxic Pollutant Standards. Documentation of toxic pollutant standards violations is the collection of evidence to support litigation against the discharger of a toxic substance(s). This activity is to be conducted as needed, based upon reports, observations, or the nature of the discharge. Chain-of-custody procedures are necessary.

Evaluation of Compliance With Pretreatment Standards. Where applicable to the State's program, at least annual evaluation of compliance with pretreatment standards should comprise a part of the compliance monitoring program. This program component includes:

1. Periodic review of municipal ordinances relative to pretreatment of industrial wastes discharged to publicly owned collection and treatment systems.
2. Review of pertinent reports, e.g., self-monitoring, GPSF files.
3. Evaluation of loads and concentrations of the influent to, and the discharge from, the publicly owned system.
4. Evaluation of monitoring and enforcement procedures by the public entity.
5. Review of inventories of new connections to the system. Chain-of-custody methods should be discretionary according to the likelihood of litigation.

Documentation of Emergency Powers Cases. Emergency powers cases under Sec. 504 of PL 92–500 are part of the Federal program. In cases where serious problems are encountered in the course of regular activities or by citizen complaints, the State should notify EPA of the situation and present evidence as required by PL 92–500. (Documentation of emergency powers cases is the collection of evidence to support litigation by the Federal government for injunctive relief against dischargers causing ". . . imminent and substantial endangerment to the health or the welfare of persons . . .")

Identifying Nonfilers. Identification of nonfilers may be accomplished in a number of ways. Remote sensing (e.g., flyovers using infrared photography)

may be useful in high population areas, but usually nonfilers are located by searching through manufacturer's indices, talks with municipal or county officials, checks of phone book yellow pages, etc., or by stream surveys.

COMPLIANCE MONITORING SAMPLING

In addition to the quality assurance techniques in Part VI, the following points should be considered in carrying out an effective compliance monitoring program.

Relevance of Data

Data gathered by field and laboratory activities must match the stipulations of the discharge permit in question and be appropriately flow weighted. For purposes of case preparation monitoring, the following paragraphs describe recommended sampling and measurement definitions which may be applied to specific permit limitations.

1. Instantaneous maxima are those that occur at any single moment in time. This is determined by the analysis of a "grab sample."

   "Grab samples" are individual samples collected over a predetermined period usually not exceeding 15 minutes. The volume of sample should be sufficient to provide any necessary replicate aliquots for the analyses required. Where needed as a safety precaution or as evidentiary support, field measurements and observations should be made by more than one person.

   Nonrepresentative samples of effluents containing materials not uniformly dispersed, e.g., "oil and grease," cannot be subdivided into aliquots. Grab samples of such effluents should be taken in replicate, one after another in a minimum time from the same sampling point to provide adequate volume for laboratory analysis.

2. One-day average conditions. The time frame for the expression of limitations is a production day or as otherwise stipulated in the applicable permit. Where the nature of the effluent will allow (absence of separating, interacting, or unstable components), compliance with 1-day average conditions is determined by analysis of a daily composite sample or an average of the analytical results from a number of individual samples. In most cases, the composite itself acts as a 1-day average and can be used for subdividing into various aliquots for subsequent laboratory analysis, necessary replicates, and spikes for quality control.

   In those cases where a 1-day average concentration is required and a sample cannot be composited, such as oil and grease, or for time dependent determinations, individual grab samples should be collected within prescribed time intervals, analyzed individually, and average value calculated. Sampling for calculation of weekly or monthly conditions should be by the same techniques over a production week or month.

Sample Collection and Handling

Procedures must be instituted for assuring sample integrity during collection, transportation, storage, and analysis. These procedures must protect against misidentification, loss or error of data relating to sampling, theft, loss, damage, or alteration of the sample. In those cases where samples are being collected for evidence, the integrity of the sample must be guarded and thoroughly documented through chain-of-custody procedures. A chain-of-custody procedure is described in Part VI, QUALITY ASSURANCE.

If the permittee requests split samples or coincident measurements or observations, the following procedures are recommended:

1. Double volume samples should be mixed and divided evenly.
2. Grab samples should be taken alternately in the same manner by the State personnel and the permittee representative.
3. Instrument readings and observation of special conditions should be taken jointly by the permittee and by State personnel.
4. In the event that the State supplies a sample to the permittee, this transfer should be made at the sampling site where possible and receipted by the permittee who will be responsible for subsequent steps of preservation, transport, and sample integrity. Splitting aliquots should be done in a manner to assure that all aliquots are homogeneous. This means the sample must be agitated during the aliquoting procedure.

Flow Measurement

Independent gaging of the larger point sources, for example, a waste treatment plant with a discharge of 20 million gallons per day—will generally not be feasible. Readings from the permittee's flow gaging equipment may be used after calibration by the sampling crews or other acceptable certification.

UNIT MANPOWER REQUIREMENTS FOR MAJOR DISCHARGER MONITORING

Estimated man-days required for each compliance monitoring program component are presented below. Total manpower requirements can be obtained by estimating the number of units of each component in the program to be conducted and accumulating those that must be carried on concurrently.

Allocation of resources for investigation of complaints should be a standard part of each year's budget. Complaints are expected to increase with public expectation of cleanup resulting from permit programs, etc.

Application Verification (3 Man-Days Per Permit)

Verification of the application including requests for additional information to process the application, requests to apply for permit, familiarization with particular industrial processes, occasional travel to plantsites and occasional preparation of recommendations with supporting documentation for instituting proceedings against a discharger by the appropriate enforcement authority are estimated to require an average of 3 man-days per permit.

Plant Process Verification (4 Man-Days Per Verification)

Process verification will generally be concurrent with verification monitoring. The unit of work will include: Travel to the plantsite; familiarization with the process; onsite review of plant records, processes and waste streams, updating files; and an occasional requirement to modify or terminate a permit. Process verification generally requires an average of 4 man-days per verification.

Compliance Schedule Monitoring (6 Man-Days Per Schedule)

Review of progress reports, evaluation or progress, occasional site inspections, computer processing and updating of compliance data, modification of schedules, and actions necessary when there is failure to submit a report or there is a violation of the compliance schedule is estimated to require an average of 6 man-days per compliance schedule during the period of the schedule.

Monitoring of Compliance With Permit Conditions

Verification Monitoring. 14 man-days per verification of waste streams, any industrial waste pretreatment processes, and other activities necessary to meet State requrements. An average survey is considered to have the following characteristics: A two-man team would travel to a plant, become familiar with the physical layout, set up composite sampling equipment at up to 5 outfalls for a 24-hour sampling period, verify flow measuring and other continuous monitoring devices, remove and clean sampling equipment, and return to point of origin. This portion of verification monitoring consumes 8 man-days per verification. If additional surveys are conducted in the same vicinity a 50-percent savings may accrue on each subsequent verification.

Case Preparation Monitoring. 90–125 man-days per case (based on availability of a mobile laboratory).

These estimates for case preparation studies are based on a 7-day sampling period. It is assumed that 8 man-days for travel and setup or cleanup would be required by the field crew at each end of the survey. Typically, a 2-man team would be required for sampling the parameters of interest with composite samplers and verifying continuous monitoring devices. This effort would require about 21 man-days. Mobile laboratory requirements would demand similar travel times for a team plus 12 days to complete all analytical procedures before the laboratory can be moved. This requirement is estimated at 38 man-days. Preparation for travel, data compilation, and report writing will require an additional 15 man-days for a total of 90 man-days. Manual sampling would raise this total to an estimated 125 days.

Documentation of Violations of Toxic Pollutant Standards (30 Man-Days Per Documentation)

To follow chain-of-custody procedures, a 2-man team should be considered for a 3-day sampling period in which up to 5 outfalls may be sampled with automatic samplers. Two days for travel and setup or cleanup at each end of the surveys would also be required. Analytical support, if available at a fixed laboratory should require 6 man-days. Three

man-days should be required to prepare a report. The total requirement for a documentation is then 30 man-days. On the same basis, manual sampling would increase this requirement to 47 man-days.

Evaluation of Compliance With Pretreatment Standards (4 Man-Days Per Evaluation)

This unit of work will require an effort similar to plant process verification.

Documentation of Emergency Powers Cases

Federal only after receipt of evidence. No manpower projection made.

Identification of Nonfilers (3 Man-Days Per Identification)

This work unit will require assembly of reference materials, cross-checks with permit applications received, and usually a visit to document that suspected installations are actually nonfilers.

To determine laboratory requirements, Table V.1 presents estimates of times required for many standard and some specialized analytical procedures. Assuming that on the average the parameters measured during verification monitoring include flow, temperature, pH, BOD, TSS, COD, oil and grease, or a similar combination of parameters, the laboratory time required will be 3 man-days per verification if samples are returned to a central laboratory. Office work necessary to correlate data and prepare necessary reports probably requires an additional 3 man-days for a total of 14 man-days.

TABLE V.1
ESTIMATED NUMBER OF ANALYSES/ANALYST/DAY

Measurement	No./day/analyst*
BOD	10–15**
Solids	15
COD	15
Oil & Grease	10
TOC	30
DO	100
TKN (automated)	70
NO_2+NO_3-N (automated)	85
NH−N (automated)	85
Total P (automated)	80
Ortho P (automated)	85
Phenolics (manual)	8
Cyanide (manual)	5
Turbidity (Hack 100)	75
Alkalinity (potentiometric)	75
Acidity (potentiometric)	75
Chloride (manual)	100
Hardness (manual)	100
Sulfate (turbidimetric)	75
Arsenic (colorimetric)	10
(AA)	10–30
Selenium	10
Fluoride (probe)	100
Metals by AA (no preliminary treatment)	60
Metals by AA (with preliminary treatment)	10–30
Mercury	20
GLC	2
GLC + Mass Spec	0.5
Membrane filter analysis (total coliform, fecal coliform, and fecal streptococcus)	15
MPN analysis (total and fecal coliform-confirmed procedure)	10

* Excluding administrative overhead, chain-of-custody procedures, report writing, etc.

** Depends on type of sample (sewage, industrial, or stream). Estimates given by the EPA National Field Investigation Centers.

PART VI
QUALITY ASSURANCE

A strong program of quality assurance is required for operating an adequate water monitoring program which produces valid data. The text which follows outlines such a program and lists references which can provide full information on the subject addressed.

COMPONENTS OF A QUALITY ASSURANCE PROGRAM

Elements of an Overall Quality Assurance Program

1. Calibration of sampling equipment and flow measuring devices.
2. Calibration of direct-reading field instruments such as pH, conductivity, dissolved oxygen, temperature, and fixed continuous monitoring devices, etc.
3. Assurance of representative sampling, both as to site selection and frequency.
4. Selection of proper sample container, preservative, transport, and storage times.
5. Use of documented, effective intralaboratory quality control program that should include:
   a. Calibration and maintenance of laboratory instruments and equipment.
   b. Verification of a working standard curve.
   c. Determination of individual precision and accuracy of the test procedures.
   d. Analyses of samples approved by methodology.
   e. Use of replicate and standard or known samples to verify daily results.
   f. Use of quality control charts to document validity of data.
6. Participation in interlaboratory investigations.
7. Accurate and timely recording, storage, and retrieval of data.

Use of the Elements

An overall quality assurance program which includes the above elements requires approximately 15–20% of the resources allocated to monitoring. It should be recognized, however, that many of these elements are already an integral part of the monitoring program but may not be labeled as quality assurance techniques. Individually the elements should be applied in the following manner.

1. Calibration of sampling equipment and flow measuring devices—Sampling equipment and flow measuring devices should be calibrated according to manufacturer's specifications immediately prior to and at the end of their use in the field or more frequently if necessary. Calibration and checks should be recorded permanently.
2. Calibration of direct-reading field instruments and fixed continuous monitoring devices.
   a. Direct-reading field instruments should be calibrated according to manufacturer's specifications immediately prior to and at the end of their use in the field. In addition, spot checks should be made at reasonable intervals throughout the sampling schedule.
   b. Fixed continuous monitoring devices should be calibrated according to manufacturer's specifications and, where possible, results verified by approved manual methodology. The calibration of sensors should be checked at least weekly and preferably daily.
   c. Calibrations and checks of both types of instruments should be recorded in logbooks or other permanent records.
3. Assurance of representative sampling, both as to site selection and frequency—The survey design must assure that a sufficient number of sampling locations, types of samples, replicate samples, and the frequency of sampling will provide a valid representation of the characteristics being assessed and assure that the objectives of the survey will be met. The general subject of sampling techniques is covered in References 1–5.
4. Selection of proper sample container, preservative, transport, and storage times—References 6 and 7 should be consulted for information on sample container and preservative, and for transport and storage times. When potential enforcement or judicial proceedings are involved, the chain-of-custody procedures must satisfy State rules or laws for introduction of evidence.
5. Use of documented, effective intralaboratory quality control program—EPA approved methodology is defined in the Federal Register (Reference 8). Methods of analysis are de-

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scribed in References 9 through 13. Quality control techniques covering the elements of an overall intralaboratory quality control program, are detailed in References 14 (especially Chapter 6) and 15.

6. Participation in interlaboratory investigations—The laboratory should participate in collaborative testing evaluations of analytical methods, conducted by the Environmental Protection Agency Methods Development and Quality Assurance Research Laboratory, EPA regional offices, and other organizations in which the laboratory wishes to validate its competency. In addition, the laboratory should participate, as appropriate, in established, continuing performance evaluation programs available through governmental agencies and/or professional organizations.

7. Recording, storage, and retrieval of data—Field and laboratory personnel should keep complete permanent records to satisfy legal requirements for potential enforcement or judicial proceedings. All field and laboratory data sheets should be dated and signed by the sampler and analyst, respectively. In addition, an information system should be developed capable of preparing, screening, validating, sorting, and making available to EPA the waterwaste monitoring data collected by the State.

Resources

Laboratories (or combinations of laboratories) supporting the State water quality monitoring program should provide physical, professional, and analytical capabilities and quality assurance measures as follows.

1. Physical and professional capabilities—Physical and professional capabilities must be adequate to perform required sampling and analyses in accordance with the above elements. The skills required and the degrees of technical competency required for such physical and chemical analyses are summarized in tabular form in Reference 14, Chapter IX.

2. Quality control officer—The State should provide a Quality Control Officer who is familiar with all aspects of approved methodology and quality assurance techniques. He should maintain close liaison with the appropriate EPA Regional Analytical Quality Control Coordinator and should be responsible for the overall laboratory quality control program in his laboratory. He should report to the appropriate level, making sure that in no case is his function subordinate to an individual responsible for direct conduct of sampling or analyses. While the overall program workload will determine whether this particular position is a full-time or part-time responsibility, in most cases it should be full time.

3. Training officer—The State should provide a training officer. He may be a line supervisor or an administrative employee, but he must recognize the variations in ability and provide training to insure that professional skills are appropriate to the task. Training programs should be carried out in order to develop the required levels of competence necessary to carry out assigned functions. These programs should be carried out in full cooperation with the quality control officer and the appropriate EPA regional AQC coordinator.

4. Laboratory facilities—The State should provide a laboratory facility with an environment which is free from those levels of atmospheric contaminants which could adversely affect the desired analyses. It should be clean, air-conditioned and/or heated and have a well-lighted work area. The facility and equipment shall be maintained in a clean condition at all times to prevent sample contamination. Safety features and other facilities consistent with operational requirements should be provided.

CHAIN-OF-CUSTODY

General

Quality assurance should be stressed in all compliance monitoring and in examination of self-monitoring programs no matter what the impetus for the spot check or inspection. The successful implementation of a compliance monitoring program depends to a large degree on the capability to produce valid data and to demonstrate such validity. No other area of environmental monitoring requires more rigorous adherence to the use of validated methodology and quality control measures.

It is imperative that laboratories and field operations involved in the collection of primary evidence prepare written procedures to be followed whenever evidence samples are collected, transferred, stored,

analyzed, or destroyed. A primary objective of these procedures is to create an accurate written record which can be used to trace the possession of the sample from the moment of its collection through its introduction into evidence. The procedures described here have been successfully employed and are presented as suggested procedures insofar as they fulfill the legal requirements of the appropriate State legal authority.

Preparation

The evidence-gathering portion of a survey is characterized by the absolute minimum number of samples required to give a fair representation of the effluent or water body sampled. The quantity of samples and sample locations are determined prior to the survey.

Chain-of-custody record tags are prepared prior to the actual survey fieldwork and contain as much information as possible to minimize clerical work by field personnel. The source of each sample is also written on the container itself prior to any field survey work.

Field logsheets used for documenting field procedures and chain-of-custody and to identify samples, should be prefilled to the extent practicable to minimize repetitive clerical field entries. Custody during sampling is maintained by the sampler or project leader through the use of the logbook. Any information from previous studies should be copied (or removed) and filed before the book is returned to the field.

Explicit chain-of-custody procedures are followed to maintain the documentation necessary to trace sample possession from the time taken until the evidence is introduced into court. A sample is in your "custody" if:

- It is in your actual physical possession; or
- it is in your view, after being in your physical possession; or
- it was in your physical possession and you locked it in a tamper-proof container or storage area.

All survey participants should receive a copy of the study plan and be knowledgeable of its contents prior to the survey. A presurvey briefing should be held to reappraise all participants of the survey objectives, sample locations and chain-of-custody procedures. After all chain-of-custody samples are collected, a debriefing should be held in the field to check adherence to chain-of-custody procedures and to determine whether additional evidence samples are required.

Sample Collection

1. To the maximum extent achievable, as few people as possible handle the sample.
2. Stream and effluent samples are obtained using standard field sampling techniques. When using sampling equipment it is assumed that this equipment is in the custody of the source being sampled.
3. The chain-of-custody record tag is attached to the sample container when the complete sample is collected and contains the following information: Sample number, time taken, date taken, source of sample (to include type of sample and name of firm), preservative, analyses required, name of person taking sample, and witnesses. The front side of the card (which has been prefilled) is signed, timed, and dated by the person sampling. The tags must be legibly filled out in ballpoint (waterproof ink). Individual sample containers or group of sample containers are secured using a tamper-proof seal.
4. Blank samples are also taken. Include one sample container without preservative and containers with preservatives from all of which the contents will be analyzed by the laboratory to exclude the possibility of container contamination.
5. The Field Data Record logbook should be maintained to record field measurements and other pertinent information necessary to refresh the sampler's memory if he later takes the stand to testify regarding his actions during the evidence gathering activity. A separate set of field notebooks should be maintained for each survey and stored in a safe place where they can be protected and accounted for at all times. Standard formats have been established to minimize field entries and include the date, time, survey, type of sample taken, volume of each sample, type of analysis, sample number, preservatives, sample location, and field measurements. Such measurements include temperature, conductivity, DO, pH, flow, and any other

pertinent information or observations. The entries are signed by the field sampler. The preparation and conservation of the field logbooks during the survey is usually the responsibility of the survey coordinator. Once the survey is complete, field logs should be retained by the survey coordinator, or his designated representative, as a part of the permanent record.

6. The field sampler is responsible for the care and custody of the samples collected until properly dispatched to the receiving laboratory or turned over to an assigned custodian. He should assure that each container is in his physical possession or in his view at all times, or is locked in such a place and manner that no one can tamper with it.

7. Colored slides or photographs are often taken which show the outfall sample location and any visible water pollution. Written documentation on the back of the photo should include the signature of the photographer, time, date, and site location. Photographs of this nature, which may be used as evidence, are handled by chain-of-custody procedures to prevent alteration.

Transfer of Custody and Shipment

1. When turning over the possession of samples, the transferee signs, dates, and times the reverse side of the chain-of-custody record tag or record. Custody transfers, if made to a sample custodian in the field, are made for individual samples. The chain-of-custody tag or card must be dated and signed by the second person who takes custody. If a third person takes custody, he must follow the same procedure. An additional custody tag or card is filled in by persons who thereafter take "custody." Therefore, the number of custodians in the chain should be as few as possible. Additional cards should be numbered consecutively.

2. The field custodian or field sampler, if a custodian has not been assigned, ordinarily has the responsibility of properly packaging and dispatching samples to the proper laboratory for analysis. A "Dispatch of Sample" portion of the chain-of-custody record tag or card should be properly filled out, dated, and signed.

3. Samples must be properly packed in shipping containers such as ice chests to avoid breakage, and the shipping containers padlocked for shipment to the receiving laboratory.

4. All packages should be accompanied by a "Sample Transmittal Sheet" showing identification of the contents. The original and one copy generally accompany the shipment and copies are mailed directly to the laboratory, to data management personnel, and to any other responsible agent. One copy is usually retained by the survey coordinator.

5. If sent by mail, the package should be registered with return receipt requested. Hand delivery need only be recorded in the logbook. Receipts from post offices and bills of lading should be sent to be retained by the laboratory custodian as part of the permanent chain-of-custody documentation.

6. If samples are delivered to the laboratory when appropriate personnel are not there to receive them, the samples should be locked in a secure area where no one can tamper with them. It is necessary that the same person unlock the samples and deliver custody to the appropriate custodian.

Laboratory Custody Procedures

The following procedures are recommended by EPA's National Field Investigation Centers and are suggested to the State insofar as they satisfy the State's statutory and regulatory requirements.

1. The laboratory directory designates one full-time employee (usually the laboratory supervisor) as a sample custodian and one other person as an alternate. In addition, the laboratory sets aside a "sample storage security area." This is a clean, dry, isolated room which can be securely locked.

2. All samples are handled by the minimum possible number of persons.

3. All incoming samples are received only by the custodian or, in his absence, the alternate, who indicates receipt by signing the sample transmittal sheets and, as appropriate, sample tags, accompanying the samples and retaining the sheets as permanent records.

4. Immediately upon receipt, the custodian places the sample in the sample room, which is locked at all times except when the samples are re-

moved or replaced by the custodian. To the maximum extent possible, only the custodian is permitted in the sample room.

5. The custodian ensures that heat-sensitive or light-sensitive samples, or other sample materials having unusual physical characteristics, or requiring special handling, are properly stored and maintained.

6. Only the custodian, or in his absence, the alternate, distributes samples to, or divides them among, personnel performing tests. The custodian enters into a permanent logbook the laboratory sample number, time and date, and the name of the person receiving the sample. The receiver also signs the entry.

7. Laboratory personnel are then responsible for the care and custody of the sample until analytical tests are completed. Upon completion of tests the unused portion of the sample together with all identifying tags and laboratory records are returned to the custodian, who records the appropriate entries in the logbook. These, and other records are retained until required for trial.

8. The analyst records in his laboratory notebook or worksheet the name of the person from whom the sample was received, whether it was sealed, identifying information describing the sample (by origin and sample identification number), the procedures performed, and the results of the testing. If deviations from approved analytical procedures occur, the analyst is prepared to justify this decision under cross-examination. The notes are signed and dated by the person performing the tests. If that person is not available as a witness at time of trial the government may be able to introduce the notes in evidence under the Federal Business Records Act.

Samples, tags, and laboratory of tests may be destroyed only upon the written order of the laboratory director, who ensures that this information is no longer required.

QUALITY ASSURANCE FOR BIOLOGICAL MONITORING

Overall Time Allocated for Quality Assurance (15 percent)

1. Intralaboratory quality assurance—10 percent.
2. Interlaboratory quality assurance—5 percent.

Intralaboratory Quality Assurance

1. Maintain laboratory reference collection of organisms of known identity.
2. Provide in-service training on identification and other sample analyses. (Use outside specialists where necessary for identification of difficult specimens.)
3. Employ a staff of sufficient size and training to permit specialization.
4. Analyze "blind" split samples prepared by the laboratory supervisor. Provide replicate analyses of samples which are not known by analyst to be "check" samples.
5. Assure proper instrument calibration and maintenance for all sampling and analytical instruments.

Interlaboratory Quality Assurance

1. Use EPA biological methods studies and reference samples including:
   a. Microscope calibration, particle counting, and sizing (simulated plankton sample).
   b. Phytoplankton count and identification.
   c. Chlorophyll extracts for spectrophotometric and fluorometric analyses.
   d. Macroinvertebrate identification sample.
   e. Diatom species proportional counts and identification.
   f. Macroinvertebrate picking, counting, and identification.
   g. Zooplankton counting and identification.
   h. Plankton biomass measurement.
   i. ATP measurement.
2. Split samples are analyzed by EPA biologists.

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